DIMENSIONS NBS

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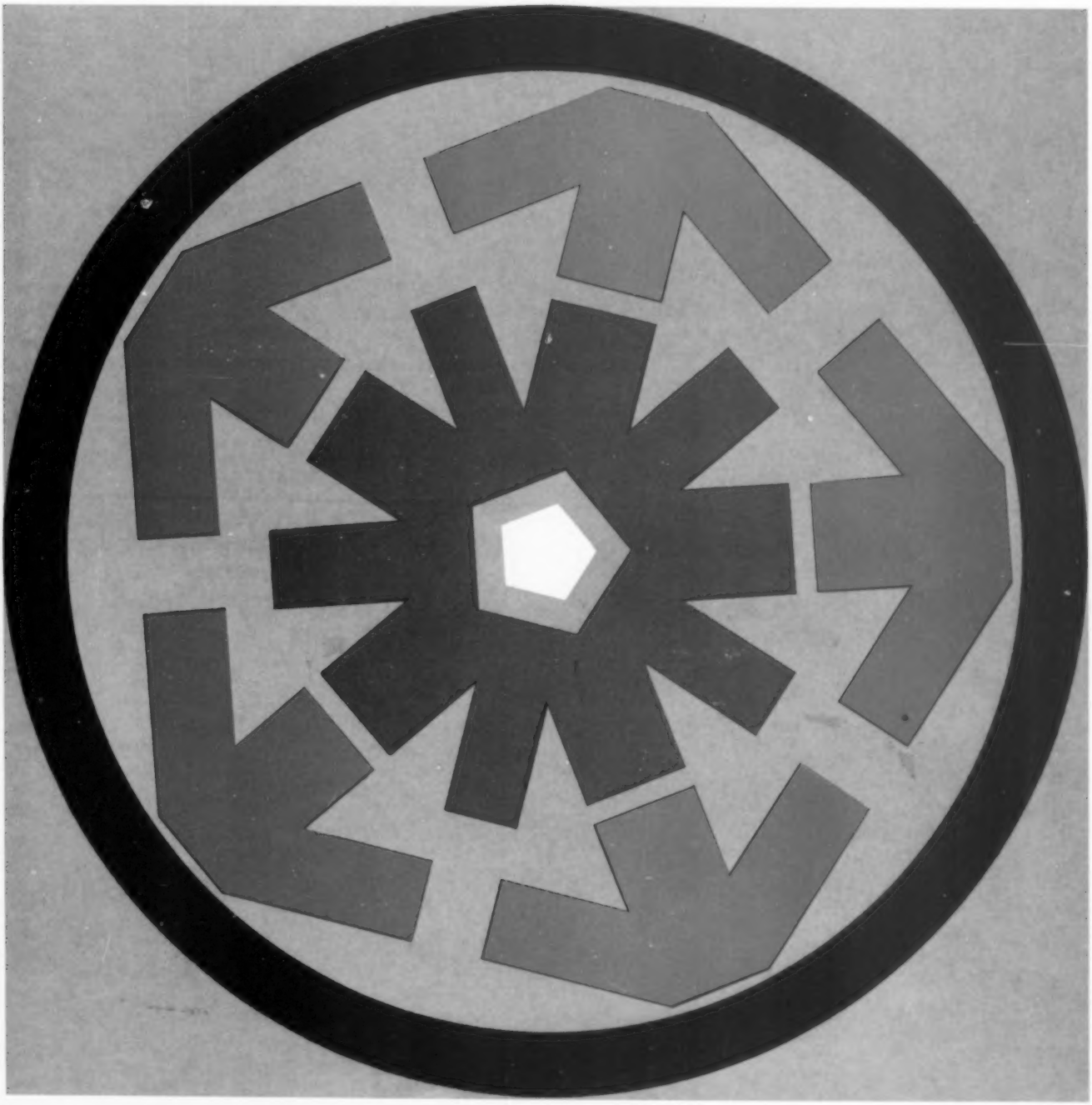
April 1978



FUSION. *See Page 14.*

COMMENT

CENTER FOR ABSOLUTE PHYSICAL QUANTITIES

*The first major reorganization of the National Bureau of Standards in 13 years is being completed this month. Under one new entity, the Center for Absolute Physical Quantities, some of the most fundamental—and traditional—areas of NBS research will continue.**

Since its earliest days, NBS has pursued the study of the fundamentals of physics through application of the science of accurate measurement, and its successes in this endeavor have contributed significantly to the preeminence of U.S. science and technology. These achievements were possible because we at NBS were fortunate to have on our staff imaginative and productive physicists who were indoctrinated in the principle of careful measurement and were given sufficient lattitude in their intellectual pursuits.

Historical examples abound. Experiments such as those by E. B. Rosa and N. E. Dorsey in 1907 on the speed of light and P. R. Heyl on the gravitational constants gave NBS, early on, an international reputation for the measurement of fundamental constants. The inquiring mind and technical skills of W. W. Coblentz set the standards for radiometry and opened the field for infrared spectroscopy. The unique combination of scientific expertise represented by Ambler, Hudson, Hayward, and Hoppes produced experimental proof that parity was not conserved in weak interactions and brought about a worldwide explosion of activity in low energy particle physics.

The Center for Absolute Physical Quantities intends to carry on this tradition of advancing science in general and the science of measurement in particular by originating and developing new ideas and subjecting these ideas to the test of careful and precise measurement.

Today, as in the past, good science and advanced technology are equally essential if NBS is to meet its responsibility for maintaining the foundation of the nation's physical measurement system. The advancement of scientific knowledge benefits, in turn, from our application of the expertise of measurement to the study of fundamental physical processes.

All physical measurements made in this country are ultimately beholden to two phases of NBS endeavor: the establishment of accurate definitions of the base quantities and units for *length, mass, time, temperature, electric current,* and the *quantity of matter;* and the establishment of consistent values for the *physical constants,* which serve as a measurement base for physics and whose relationship we utilize to test the consistency of our measurement system and the validity of our postulated physical laws. We in the Center for Absolute Physical Quantities are currently involved in a number of experiments aimed at improving our knowledge of physics and at building a more accurate foundation for physical measurements.

The definition that serves as the basis of all length measurements, for example, is now being challenged in a revolutionary series of experiments in which the frequency of optical radiation is being measured relative to our present definition of time: the frequency of an atomic transition in the cesium atom. The first benefit derived from this work was a new and more accurate measurement of the speed of light. We can now also dispense with a separate definition of the unit of length and define length in terms of the distance traveled by light in a given time. A proposal by NBS, which is under discussion at the international level, would define the meter as the distance traveled by light in $(299\ 792\ 458)^{-1}$ seconds. In a complementary series of experiments, highly stable laser systems have now achieved frequency stability that challenges that of the cesium frequency standard.

In another application of precision length measurement, we have utilized a combination of x-ray and optical interferometry to measure very precisely the lattice distance between atoms in a perfect single crystal of silicon. That work has succeeded in establishing a new wavelength scale in the x-ray and gamma-ray regions that is tied to the length of the meter. Application of this new scale to observations in high energy physics has resulted in the resolution of several fundamental disagreements which had developed as a result of previous measurements performed on inconsistent scales. An important additional benefit derived from these lattice measurements was the determination of a new and more accurate value of Avogradro's number, which defines the quantity of matter.

Electrical measurements, and particularly the ability to measure the volt, are greatly improved today as the result of our application of low temperature physics and the Josephson junction to voltage measurements. A modification of the same basic technology is being used to realize the thermodynamic scale of temperature in the very low (cryogenic) region. The Center develops and maintains a scientific competence in a range of disciplines from x-ray physics to astrophysics. The Center is a partner, with the University of Colorado, in the Joint Institute for Laboratory Astrophysics, and is engaged in a variety of cooperative projects with other groups, both in and outside NBS, in areas of research where accurate measurement is a crucial element. We hope to strengthen these ties and to establish the Center as a major scientific resource for NBS and the nation.

K. G. Kessler

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*The June issue of DIMENSIONS/NBS will discuss the NBS reorganization in detail.

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THE FLY'S EYE TELESCOPE

by Frederick P. McGehan

OBSERVING the moon has romantic possibilities, as most people have probably already discovered. But it also holds a great deal of potential for revealing some of the still undisclosed secrets of this earth—or for that matter this universe.

McGehan is a public information specialist with the NBS Boulder Program Information Office.

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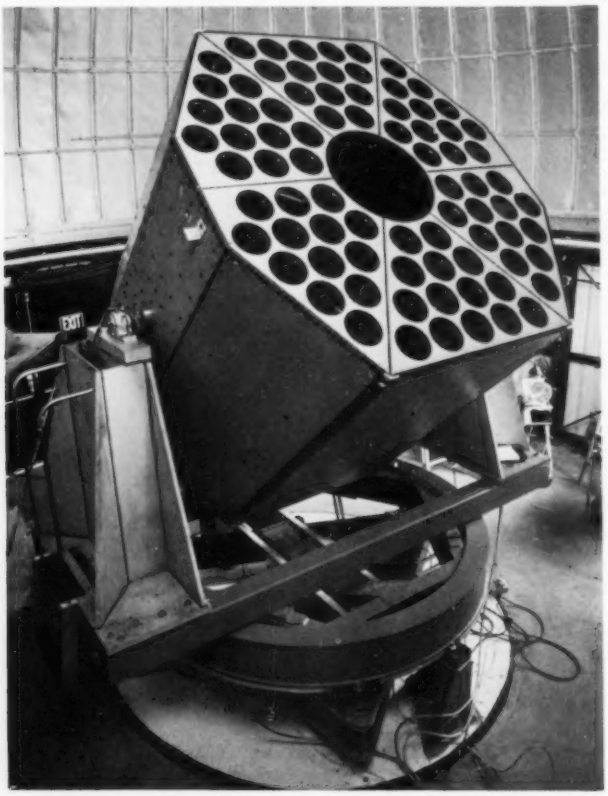
Scientists involved in the lunar ranging program are trying to probe those secrets by timing the journey of laser light to the moon and back. The distance measurements made possible by this kind of experiment represent only a small part of the knowledge that the researchers hope to obtain—knowledge that may, for instance, reveal something about the wobbling of the earth's poles and the moon's irregular rotation.

To make this kind of moon monitoring more efficient, a new telescope has been invented. The National Bureau of Standards in Boulder, Colorado, has been intimately involved with this development, but the story did not begin there.

It began at Wesleyan University, Middletown, Connecticut, in 1969 in the physics laboratory of Professor James E. Faller. Faller was involved with early plans for placing retroreflectors (ultra-precise versions of the reflectors used on bicycles and traffic signs) on the surface of the moon, bouncing laser beams off them, and capturing the beams with earth-bound telescopes. It was in July 1969 that the Apollo II astronauts first placed an array of retroreflectors on the moon. Faller was part of a team at the Lick Observatory, Mt. Hamilton, California, that obtained the first capture of the reflected light. Two other array packages were put in place by succeeding astronauts.



The lunar ranging telescope in its observatory on Maui. In April 1977 scientists made the first successful ranges with the complete system designed for the Haleakala station.

Faller and one of his students, Michael P. Sulzer, the son of a former NBS scientist and a senior at Wesleyan, were interested in designing a telescope that would take maximum advantage of the lunar retroreflector apparatus. Faller noted that telescopes have been designed traditionally for a broad range of astronomical activities. As a result, they are massive and quite expensive. He wondered whether a different type of telescope could be designed to handle the more limited activities of lunar ranging—to look effectively at a point source which requires a large aperture but only a narrow field of view. Instead of having one large optical element (a lens or a mirror), the device could have an array of elements, in this case lenses. Faller reasoned that these factors would reduce both the weight and the high cost of the apparatus.

Sulzer accepted his professor's challenge and worked over the summer in a basement machine shop to develop a mock-up of such a telescope. He used this project for his senior (honors) thesis. Sulzer got an "A" and Faller got the idea of interesting the National Aeronautics and Space Administration (NASA) in underwriting the cost of building such a telescope. The professor proposed to develop a mobile telescope that could be used to "range" the moon from various locations in the United States in order to gather more data about both the moon and earth than could be obtained from fixed observatories. NASA was interested in the idea, and Faller worked with Richard Young, director of Wesleyan's physics machine shop, to turn the mock-up into a reality.

Before the project could be completed, Faller took a position with NBS in 1972 at the joint Institute for Laboratory Astrophysics (JILA), operated by NBS and the University of Colorado. So, along with his luggage, Faller brought with him to Boulder the unfinished bits and pieces of his new telescope. With the aid of JILA, NBS, and the University of Colorado machine shops, the parts were fitted together in a large room on the first floor of the JILA building on the university campus. Faller describes the telescope as "not particularly elegant in appear-

LUNAR RANGING

Lunar ranging involves measuring the distance between points on the earth and the moon by timing the roundtrip journey of a pulse of light returned to earth by retroreflectors on the moon. Scientists then use these range measurements, and in particular their variations with time, to study aspects of the earth, the moon, and the earth-moon system.

In the late 1950's, Princeton University scientists in gravitational research proposed using a pulsed searchlight for tracking the angular position of an artificial satellite. Then, with the advent of pulsed lasers, ranging measurements became possible and permitted much more accurate tracking not only of satellites but also the moon. In 1962, researchers at the Massachusetts Institute of Technology demonstrated this technique by detecting laser light reflected from the lunar surface. The regular U.S. ranging program began when the Apollo 11 crew placed a retroreflector on the moon in July 1969. Initial measurements were made at the Lick Observatory (Mt. Hamilton, California) until facilities for a long-term program were set up at the McDonald Observatory (Ft. Davis, Texas). Lunar ranging is now an international scientific activity: a number of other countries have their own ranging stations or are in the process of establishing them.

ance . . . it looks more like a First World War mortar."

It *is* squat, and, to the untrained eye, somewhat homely, but it is also perhaps one-half the cost and weight of a conventional telescope. It contains an array of 80 lenses, each 19 centimeters in diameter. To biologically-trained observers, the lens arrangement resembles the eye of a fly, hence the nickname "fly's eye telescope." Before the project was completed, funds and/or other support came from NASA, Wesleyan University, the Alfred P. Sloane Foundation (Faller was a Sloane Fellow in 1972), and NBS.

During that period when the telescope was being assembled at JILA, the question arose as to how it could best be used in the lunar ranging program. The McDonald Observatory in Ft. Davis, Texas, was then the only station regularly obtaining range measurements from the lunar retroreflectors; a second station was essential in order to increase the amount and type of data and, in turn, improve the accuracy of the scientific results by permitting the analysis to take full advantage of the 2-to-6-centimeter ranging accuracy.

Initial discussions centered on a second facility in Hawaii, Faller says, because (among other reasons) Hawaii is on the Pacific tectonic plate instead of the continental U.S. plate. If one (or both) plates are moving, this could be determined from differences in the ranging data gathered at the two stations. There were discussions with the Defense Department's Advanced Research Projects Agency, which operates a rocket and satellite tracking station on Maui. These were not fruitful because the lunar ranging project would frequently have had to take a back seat to defense-oriented objectives.

Peter L. Bender, another JILA scientist and, like Faller, a member of the lunar ranging experiment scientific team, suggested "making our own" lunar ranging station by using Faller's telescope as the receiver and getting other members of the team to provide other components. The University of Hawaii was asked to construct the laser transmitter and the University of Maryland had responsibility for the electronics work. "It was like a scientific potluck," Faller explains. The site chosen was at the 3000-meter summit of Mount Haleakala on Maui.

With the future of the telescope settled, its completion posed the question of transporting it to Maui. Faller had originally intended to take the front, back and side plates off the telescope in order to get it outside the JILA building. But the internal workings became too complex ("there got to be a lot of bells and whistles inside," in Faller's words) and the scope had to be moved as a single unit. "It was a case where the bread landed with the jelly up," Faller says in explaining that the 2.5 metric-ton scope just barely squeezed through the JILA doors and hallways with the assistance of professional movers. It was driven to San Francisco in August 1976, placed aboard a freighter for Honolulu, taken by barge to Maui, and finally trucked to the observatory.

The entire system was operational and the first successful ranges with Faller's telescope were achieved last April. It is now the only station in the world specifically designed for this work. Lunar ranging scientists at the McDonald Observatory must share time with other uses and priorities of their 270-centimeter diameter telescope. Nevertheless, McDonald is responsible for almost all of the data obtained during the first eight years of lunar ranging and continues actively in the program.

The observatory in Hawaii permits additional measurements and data gathering that could not be accomplished with McDonald alone. The dual operation, for example, permits more continuous

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In addition to increasing our knowledge about the earth, the lunar ranging telescopes will, of course, add to our store of knowledge about the moon.

ranging of the moon, reducing the down time caused when foul weather covers one station.

One aim of the lunar ranging program that is made possible by having two observatories is to measure continental drift. It is believed that the crust of the earth is composed of large segments (tectonic plates) that move with respect to each other. Hawaii, for example, is believed to be moving about 10 centimeters a year towards Japan. Faller expects to be able to obtain the "first, real-time measurements" of continental drift within several years. "You will be able to obtain today's rate of motion instead of a million-year average," he says. This should be able to establish whether the movement is uniform in rate or is episodic.

Data from the two observatories are expected to reveal the position of the North Pole within about 3 or 4 centimeters, or about 10 times more accurately than is now known. The Bureau International de l'Heure, Paris, now provides data on the pole movement that is accurate to about 40 centimeters. The pole moves in a complicated elliptical path and may travel nearly 600 meters in a year's time. Just why the North Pole "wobbles" is uncertain. There is one hypothesis that it shifts with major earthquakes—either just before or just after. Thus better measurement of the pole's movements may lead to a better understanding (possibly even greater predictability) of earthquakes.

In addition to increasing our knowledge about the earth, the lunar ranging telescopes will, of course, add to our store of knowledge about the moon. We will be able to measure more precisely the motion of the moon in its orbit and the irregular rotations of the moon about its center (called lunar librations). Improvement in measuring the librations should provide the data to better calculate the moon's distribution of mass. This, in turn, may lead us to new knowledge of the moon's history.

When the Hawaii station is operational, Faller predicts a "rich harvest" of scientific data. He notes:

"Clearly, for years to come we can look forward to the rich scientific harvest that was the motivating factor in the experiment's conception and the placement of the retroreflector arrays on the moon's surface."

Being one of the fathers of the lunar ranging experiment, Faller knows whereof he speaks. □

A TECHNICAL LOOK AT THE TELESCOPE

by David Orr

Laser light returned to earth by a lunar reflector is a plane wave enfeebled by a 770-000-km journey. The telescope which detects this tenuous signal must intercept as much of it and as little of the moonshine as possible. Jim Faller therefore designed his telescope with a large aperture and a small field of view.

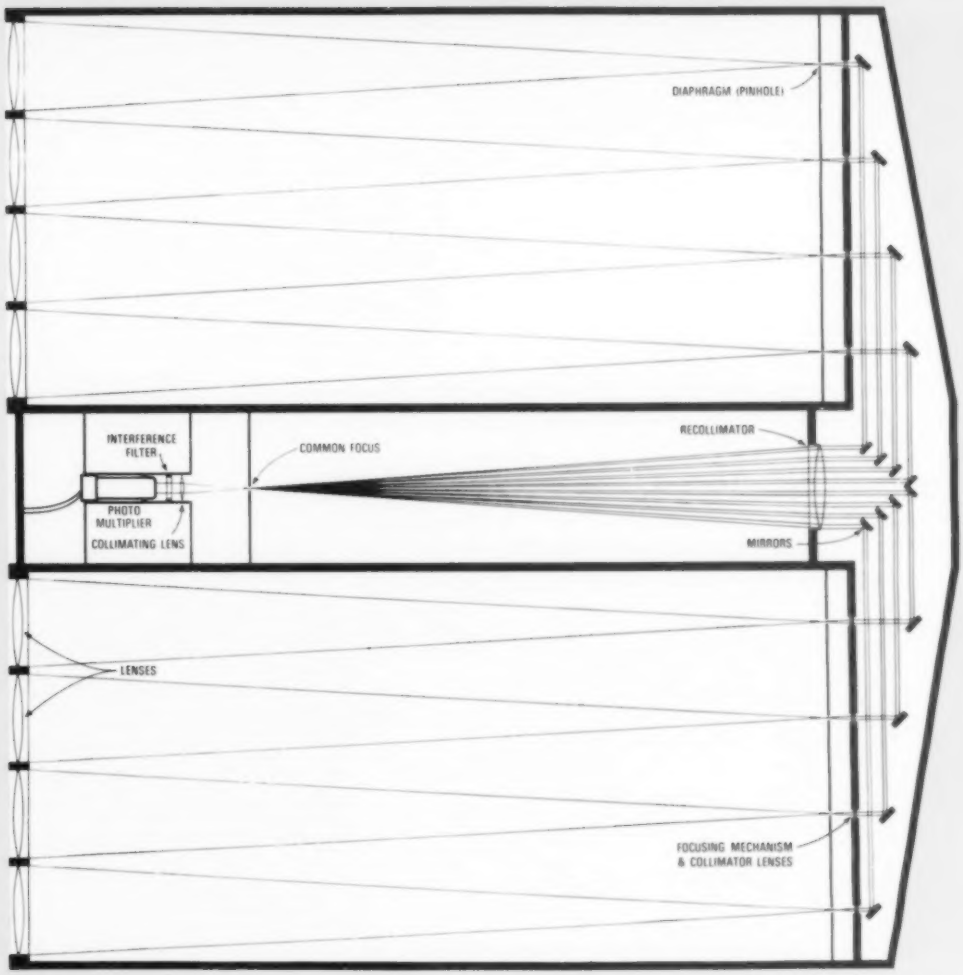
Light entering the objective lenses in a given row around the telescope face has equal optical paths to the photomultiplier. Thus, when a plane wave enters the 80-lens array, the light from a given row of lenses arrives at the photomultiplier in coincidence. At the back of the telescope, a matching array of 0.13 millimeter pinholes limits the angular field of view to no more than 11 seconds of arc. Mirrors then direct the 80 beams through a common focus, after which the resultant beam is split and detected by two photomultiplier tubes. The output of each tube goes to a dual-channel multievent timer. A variable pinhole at the common focus can be used to reduce the angular field to as little as 3 seconds. This minimum field covers an area on the moon about 6 kilometers in diameter. (The moon's diameter is 3460 kilometers.)

The Lick telescope on Mt. Hamilton weighs 41 metric tons (excluding supports and bearings), of which 3.9 metric tons are the mirror. A relative flyweight, Faller's multilensed telescope and its bearing total 3.6 metric tons, with the 80 lenses of its "fly-eye" accounting for just 300 kilograms.

Successful operation of the telescope depends on the various apertures remaining aligned when the telescope points to different parts of the sky. To ensure this, the front and back plates are solidly connected together by the side panels and the framework to which these attach. The telescope's construction and light weight give it great rigidity as it lifts and turns to intercept and follow the moon.

The telescope has so little flexure that aiming it by visual setting should not be neces-

Orr is a public information specialist with the NBS Boulder Program Information Office.



Light enters the multilensed telescope through the objective lens array (left) and is directed by mirrors (right) to the photomultiplier detector (left center).

sary: after the present "shakedown" trials, it should point to within a few seconds of arc of the direction to which it is set. Lunar ephemeris (the moon's angular position) data have a comparable uncertainty. Thus, when performing up to the specifications of all its components, the telescope will have within its field the lunar ephemeris coordinates entered on the elevation and azimuth controls (vertical and horizontal angles).

The capability for "blind" pointing makes possible fully automated operation. Through shaft encoders on the telescope's elevation and azimuth axes, a computer continuously aims the telescope. The same computer will check the range electronics, record and store the data, and correct the preprogrammed angle ephemeris for possible flexure and encoder zero error. Running the telescope by computer eliminates operator-related expenses, and should result in a considerable saving over the lunar ranging program's expected 10-year lifetime.

The multilensed telescope is not limited to a single-minded stare at lunar retroreflectors. It can also be employed in studies of stellar spectroscopy, photometry, and point-source astronomy. Work in these areas composes more than half of modern observational astronomy.

Though Faller did not design the telescope to be an image-forming instrument, it nevertheless could function as one. Each objective lens forms an image of what it looks at, and the part of this image passed by field-limiting apertures is present at the common focus. These 80 narrow-field images could be brought into coincidence by inserting a dove prism into the parallel-ray portion of each light beam traversing the back plate. The telescope, with its 11-second-of-arc field of view, would then operate as an imaging instrument rather than just a light detector.

MEASURING WITH MICROWAVES

by Kenneth Armstrong

You may not be directly involved in coal mining or farming, but you are certainly affected by these operations. Also, there's a chance that you enjoy snow skiing or that you will one day construct something on your property like a concrete patio or driveway. Each of these unrelated activities could be improved in terms of efficiency or safety—or both—by developments in the science of measurement.

In the Boulder, Colorado, laboratories of the National Bureau of Standards, scientists are working on remote-sensing microwave measurement systems. They will give faster, cheaper, and more complete information than is currently obtainable for deciding such things as whether the ceiling of a mine tunnel has been worked to the maximum safe extent or whether a snowpack in the mountains is likely to result in an avalanche. Less dramatically, the systems could be used to determine the efficiency of various methods for watering crops, the strength of concrete, or the amount of moisture in soil.

"Microwave sensing begins with high frequency radio waves that are projected into the material to be measured," explains Doyle Ellerbruch, chief of the Electromagnetic Scattering Properties Section at NBS. "The reflections from within that material are received and interpreted on a cathode ray tube, which looks like a television set."

A microwave system is different from other remote sensing systems in that it is used over short distances, ranging from a maximum of about 30 meters to a minimum of a few centimeters (an inch or less). Its degree of development as a measuring tool varies according to application. For instance, the NBS experimental work is virtually finished for microwave sensing to determine the stage of concrete cure, and a prototype instrument package will be constructed this year. This will be a portable assembly that can easily be carried to construction sites. There, it will instantaneously report the condition of cure of the concrete by the way microwaves are reflected from the material's interior structure. The measurement will be completely nondestructive.

Armstrong is a public information specialist in the NBS Boulder, Colorado, Program Information Office.

Measurements in Coal Mines

Also near the prototype stage is a microwave sensing system for making critical measurements in coal mines. This equipment will control mechanized mining equipment, guiding it to follow the contour of the underground seam of coal and stopping it in the proximity of dangerous obstructions.

In the process of mining coal, it is necessary to leave 15 to 20 centimeters (6-8 inches) of coal on the ceiling of a mine tunnel for safety reasons. A seam of coal is overlaid by slate: If the slate is exposed to the air in the mine, it deteriorates and the mine caves in. The present method of determining the ceiling-coal thickness is to drill a hole every three meters (10 feet) and adjust the cut of the mining machine accordingly. If more coal is left than necessary, this reduces the yield of the mine. The microwave sensing equipment will con-

In the Boulder, Colorado, laboratories of the National Bureau of Standards, scientists are working on remote-sensing microwave measurements systems.

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Ellerbruch reads the thermometer used to measure the temperature of the snowpack at intervals from top to bottom of the pit.

He prepares the vertical surface of a pit through the snow. Manual measurements made on the vertical surface of the pit are used as references for developing the microwave measuring system.

tinuously measure the thickness of the ceiling and guide the mining machine automatically.

Other mining hazards are gas wells that were sunk through seams of unmined coal and later abandoned. In the eastern United States, there are literally thousands of such wells. Their locations, and even their existence, are often unrecorded. Even if the surface location is known, pinpointing the intersection with the coal seam is a difficult and expensive procedure. However, explosions result if the cutting blades of the mining machine hit a well casing. To avoid this, a microwave sensor will detect a casing, warn the operator, and stop the machine.

Other Devices

Another microwave measuring device, one in the early stages of development, will measure the depth of the saline (alkali) stratum of soil beneath the earth's surface. This is an important consideration in irrigation, as excessive watering brings the salt to the surface where it retards or destroys crops.

Also in the preliminary stages of development is a microwave system for measuring moisture in soil —not only the amount, but also the depth and distribution. This instrument, when it is carried over a field, will indicate when irrigation is needed. It will also indicate where water is not penetrating the soil so that corrective steps can be taken.

Another instrument that is being developed by NBS scientists on the principle of microwave sensing will measure snow. Not only will it measure depth, it will also measure water content, hardness, and stratification beneath the surface. A closer look at the development of this instrument provides an appreciation for the work involved.

"Understanding what needs to be measured and why is essential," says Ellerbruch. "We also have to learn, in some detail, about the material we are attempting to measure. Snow, for instance, doesn't just lie there until it melts. A snow bank is a dynamic mass that is continually changing in characteristics of depth, mass, water content, crystalline structure, temperature, and hardness."

Avalanche Conditions

One product of the dynamic process that Ellerbruch speaks of is "hoar." Almost everyone has seen hoar snow. It takes the form of hard, round crystals often known as "corn." Hoar is strictly second class for skiing, and it is no good for making snowballs

because the crystals will not stick together. Neither will it pack, for the same reason. Snow never falls from the sky in this form, and hoar is not always found on the surface.

The surface may be powder, ice, wind pack, or any combination of crystalline structures, while underneath—perhaps three, six, or more meters down—a layer of snow can turn to hoar if conditions are right. This is known as depth hoar: a layer of independent, hard, round, little ice crystals which do not adhere to each other. And under the "right" conditions, it can be very dangerous. For instance, imagine placing a billion billion tiny marbles beneath a megaton snowpack. If the location is a mountain and the incline is steep enough, the result will be an avalanche. When depth hoar forms under these conditions, there is only one thing to hope for—that all skiers, snowmobilers, loggers, residents, and motorists in the area can be warned to evacuate so that no lives will be lost.

Warning Service

To provide such warning, the National Forest Service has a continuing program of monitoring danger areas. Of the several indicators used to forecast an impending avalanche, depth hoar is the most difficult to ascertain. The only present method for making this determination is quite primitive: Dig a pit. Unfortunately, it is not advisable to go digging in areas where information is most needed because these areas are also the most dangerous. As a result, forecasters work with less knowledge than they would like to have.

At the same time, there is a more urgent need than ever before for the warning service because an increasing number of people are skiing the avalanche paths to avoid the crowds at regular ski areas. (The Forest Service, incidentally, strongly advises against this hazardous practice.)

Avalanche danger, however, is not the only reason for digging a pit through the snow. Pits are also dug to measure depth, water content, temperature, and hardness. Depth gives a general indication of all the other things people want to know about snow. Water content is a signal of the coming summer's water supplies. A continuing record of temperature profile is an important indicator of the strata developing within the snow bank (hoar, for instance). Loggers, forest rangers, and rescue personnel are among those interested in the hardness of snow, which lets them determine what kinds of vehicles can be safely used in the area.

Douglas Tamura, a technician in the NBS Electromagnetic Division, unloads the microwave equipment from the carryall onto a toboggan.

Manual Measurements

It is obviously easy to measure snow depth after a pit has been dug. Determining water content requires taking a measured sample, melting it, and measuring the resulting water. A thermometer, of course, is used to take the snowbank's temperature at several depths. The qualitative change in density of various layers of snow can be determined by using a plastic card. The observer draws the card edgewise from bottom to top of the snow at the face of the excavation and notes the force needed to move the card through the layers. Determining the hardness of the snowpack involves driving an iron rod, called a ramsonde or penetrometer, into the surface of the snow and counting the strokes of the driver.

In the entire process, the only hint of modern technology is the plastic card. All the other equipment and techniques were available to Hannibal when he crossed the Alps with his war elephants in 218 B.C. This primitive state of affairs may change, however, if the present experimental microwave-sensing measurement program proves successful. NBS, working in cooperation with the Forest Service, hopes to develop an instrument package that will make most of the needed snow measurements while suspended from a helicopter. In known ava-

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Tamura, wearing snow shoes, readies electronic equipment to make microwave measurements of the snowpack.

lanche-starting areas, instruments could be buried to continuously monitor the snowpack, and the information could be telemetered to a warning center.

Experimenting with Microwaves

For the past two winters, Ellerbruch and his team of scientists have made experimental microwave measurements of snow in Colorado and Wyoming. Periodically they loaded their equipment into a vehicle and drove to a location near their experimental site. There, they put on snow shoes and, pulling a toboggan carrying equipment for making both electronic and manual measurements, they walked (or mushed) the remaining distance to the site where they made their measurements. They also made careful notes of everything that might possibly be significant; they took samples of snow for water content and returned with it and their data to the laboratory for comparison and analysis.

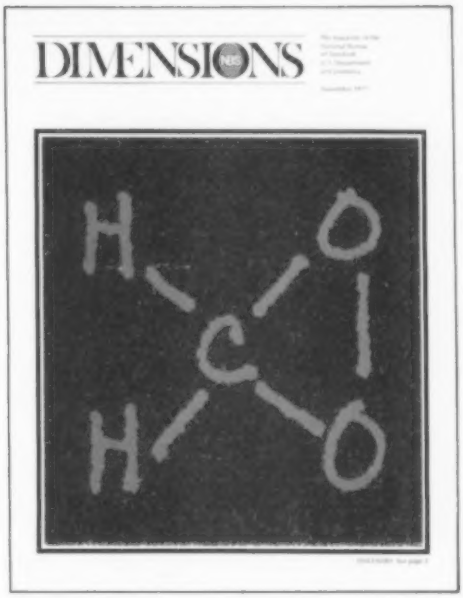
In the past, the NBS scientists had made their snow measurements from the top, with the microwave antennas looking down from the surface of the snow. This year, they took their microwave measurements from the bottom, with the antennas looking up. They accomplished this by using antennas they put in place last summer. Leads from the antennas run up poles so they can be connected to the electronic equipment at the snow's surface.

Promising Results

"Experimental results of the snow measurements are very promising," says Ellerbruch. "We may never be able to make all the measurements presently being made manually by using only one microwave-sensing measurement system, but we believe that our present microwave system, after some refining, could provide most of the information anyone wants about snow pack."

If Ellerbruch is right, it may be only a few years before old-timers will nostalgically recall bundling up in their down parkas, snowmobiling and snowshoeing to snow measurement sites, and digging pits. Maybe they will recall the numbing cold as they ungloved their hands to make notations. Perhaps they will also recall getting caught in a ground blizzard and becoming lost when their eyes froze shut. Shuddering at the recollection, they may feel a twinge of arthritis between their shoulder blades and be glad that they no longer have to dig pits in the snow high atop some mountain. □

Special for educators



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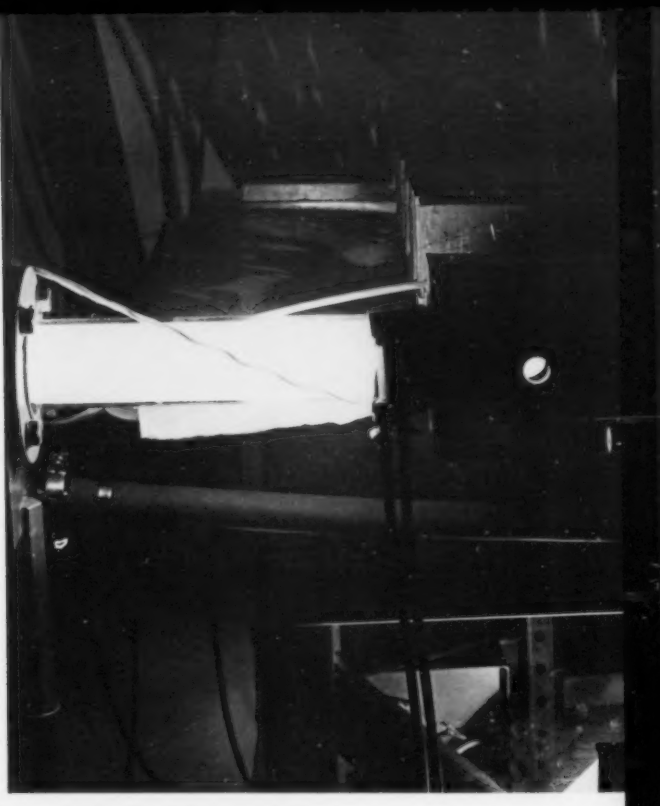
COVER STORY



FUSION REACTORS IN OUR FUTURE?

by Michael Baum

STANDING in front of you in a crowded laboratory, the test apparatus takes up a good 100 square meters of floor space and looks like nothing in particular. It's long, flat, and massive, hooked to heavy cables and tubing, and the most noticeable feature is a clear horizontal glass cylinder just over two meters long and 8 centimeters in diameter, the center third of it clamped with heavy bands of metal.

Two researchers charge the tube with gas and start the firing sequence. The tube suddenly blazes with a brilliant flash of light and a muffled thunderclap is heard.

The light doesn't last long—about four millionths of a second—but during that period you are looking into a model of the heart of a nuclear fusion reactor.

The device is called a *theta pinch*, (see box) and William Rowan and James Roberts of the National Bureau of Standards are using it to study some of the atomic processes that will take place in a fusion reactor. They do this in an ordinary physics laboratory, without ever coming close to starting a nuclear reaction. They do it by an elegant sort of "modeling" in which relatively low temperatures (1 000 000 degrees Celsius) represent unimaginably high temperatures (100 000 000 degrees Celsius) and small, light ions* become scale models of large, heavy ions.

Baum is a writer and public information specialist in the NBS Public Information Division.

Energy from Heavy Hydrogen

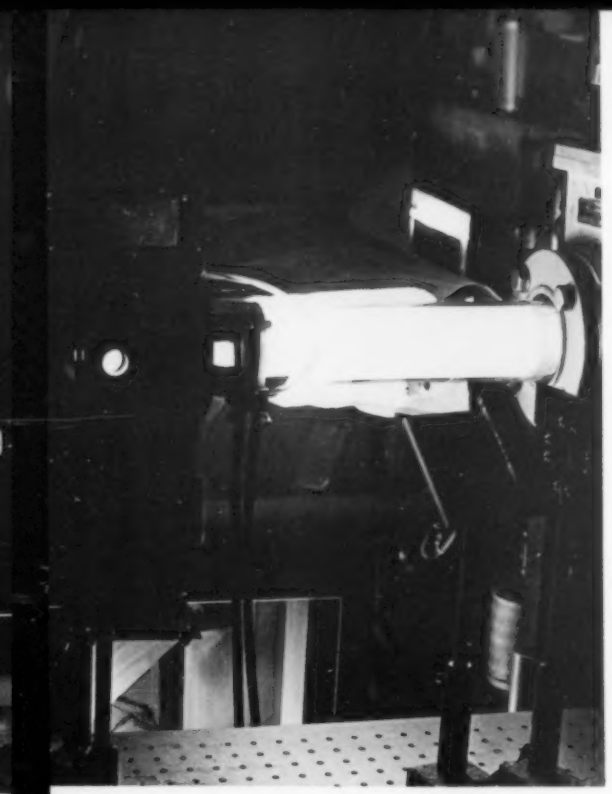
The reasons for all this are found in the basic concepts behind fusion research. There are a variety of theoretically possible nuclear fusion reactions in which the nuclei of two light atoms combine to form the nucleus of a heavier atom. The most "popular" reaction—popular because it requires considerably less energy to start than the others—is shown in this equation:

$$D + T \rightarrow {}^4He + n + 17.6\ Mev$$

Inherent in this reaction are the advantages and disadvantages common to all fusion processes. This equation begins with deuterium and tritium, the heavy and superheavy isotopes of hydrogen. Fuel for such a reaction is abundant even though there is only about one deuterium atom for every 6500 common hydrogen atoms, because deuterium can be extracted from the earth's greatest resource—water. The U.S. Department of Energy estimates that the deuterium resources, if used to supply twice the world's current energy demand, would last for about 50 billion years.

Tritium, a radioactive isotope of hydrogen, is not found in nature and therefore has to be manufac-

* Ions are atoms stripped of some or all electrons.



Brilliant light fills a theta pinch reaction chamber at NBS as the rising magnetic field heats hydrogen plasma to 1 million degrees Celsius for 4 millionths of a second.

tured. But the same fusion reactors that burn the tritium can produce it by bombarding lithium with neutron radiation. DOE estimates that *known* lithium reserves would last for almost 50,000 years.

The other side of the equation is equally promising. The main reaction product is common helium, non-polluting and non-radioactive. The reaction produces a great deal of energy, close to 90 000 kilowatt hours per gram of fuel.

The reaction also produces neutron radiation, which in turn produces radiation in the materials used to build the reactor. However, by selecting those materials carefully, the radiation hazard can be kept to a minimum.

For two reasons, fusion reactors would theoretically be many times safer than the fission reactors in operation today. First, the amounts of radioactive materials on hand in a fusion reactor are comparatively small. Second, the fusion process in a reactor cannot become self-sustaining. If the system inducing the process failed to operate properly, the reaction itself would "fail safe" simply by stopping.

Fusion looks like the rosy alternative on the basis of these comparisons, but there are other elements to consider before the picture is complete. For instance, power from fission reactors is today lighting up homes, businesses, and industries in various communities across this country. A fusion reactor has never lit a single bulb anywhere in the world. And there's the rub.

How to Make It Work

The biggest problem with a fusion reactor is how to make it work. Some technical experts doubt that it's possible to do so. The NBS theta pinch project is designed to help find out.

The extreme conditions that must be achieved and maintained pose formidable difficulties, according to Roberts, chief of the NBS theta pinch project.

In the ionized gas or *plasma*, which forms the fuel for the magnetic fusion reactor, the deuterium and tritium nuclei both carry electrical charges which tend to keep them apart. For the particles to fuse and ignite the fusion reaction, they must have a high kinetic energy (that is, be very hot) and be kept packed together for a sufficient length of time.

The deuterium-tritium reaction has by far the lowest "ignition temperature" of the fusion reactions possible in a reactor, but even this reaction takes place at temperatures of approximately 100 million degrees Celsius or more. Think of that as comparable to the temperatures in the center of the sun.

"But reaching the temperature is only part of the problem," says Roberts. "Serious considerations like radiated power losses from impurities, diffusion, and instabilities must be addressed."

Diffusion and instabilities refer to the inability of the confining magnetic field to hold the plasma together (see box). Impurities are another matter.

Impurities are free atoms torn from the walls and limiters* of the reactor and surrounding space that mix with the plasma. They can be metals like tungsten, molybdenum, and iron or gases, including oxygen. Impurities in the plasma are a crucial problem in designing fusion reactors. The most dramatic way to see why this is so is to look at the graph (shown with this article) of the ignition criteria for various fractions of impurities. (At ignition temperatures greater than 100 million degrees Celsius, an ignition criterion is the product of plasma density multiplied by time, which gives the combination of time and density necessary to produce a nuclear fusion reaction: the greater the density, the less time required for confinement.)

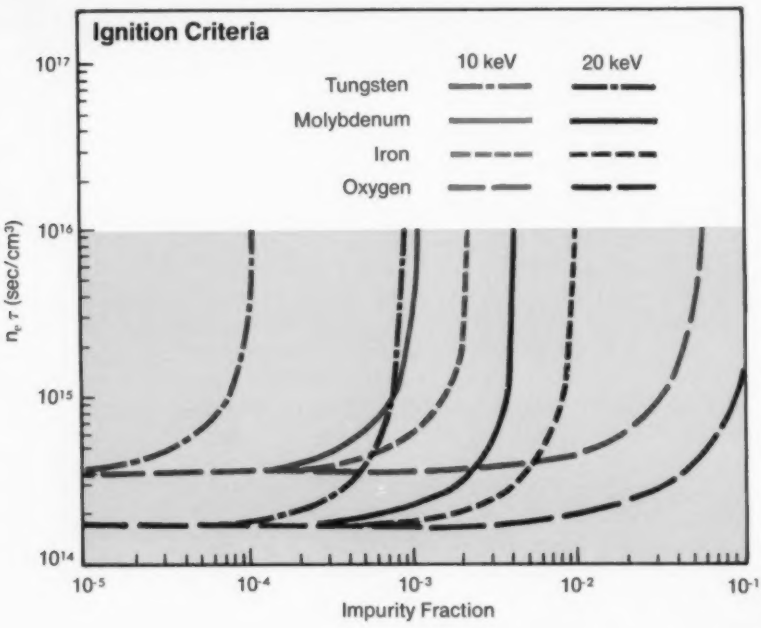
For the reaction temperature that will be reached by the first test reactors, the ignition criterion for pure fuel is over 10^{14} (a hundred trillion) seconds per cubic centimeter. But notice what happens as soon as relatively small amounts of impurities enter the plasma. The steep upswing of the curve as impurities increase shows that the criteria become higher and higher, necessary confinement times get longer and longer, and the reaction becomes impossible theoretically as well as practically.

Why? "The impurities enter the plasma, soak up energy, and radiate it by the emission of light energy. This reduces the thermal kinetic (heat) energy of the particles, which is what we need to produce fusion," explains Roberts. "With high Z (Z being atomic number) impurities, such as the heavier metals from the walls and limiters of fusion devices, it takes more energy to ionize them—to strip them of electrons."

In addition, he says, "A large amount of energy goes to the remaining electrons in the heavy impurity atoms, which can change temporarily to high

turn page

* A limiter is a device designed to keep the plasma away from the walls of the reactor.



energy states, return to their "ground" state, and give off the energy they've acquired by emission of light. That would be okay if the energy were given back to the plasma, but it's not. It's radiated as ordinary light."

Data to Build On

This is where the theta pinch comes in. "Basically what we're doing is providing atomic data to the fusion energy community—the people doing fusion research—so that they can better understand the dynamics of the plasmas," says Roberts. The project is sponsored by the Department of Energy.

The data are used to make more accurate theoretical models of the atomic processes, which in turn are used to make critical decisions about the design of the reactors—decisions such as what metals should be used to build the walls and limiters that will confine the plasma.

The project produces two basic types of data: excitation rates and ionization rates for the highly ionized atoms.

The *excitation rate* relates directly to power losses through radiation. It is a measure of the tendency of the ion to change to a higher electron energy level and then lose the power in the form of radiated light.

The *ionization rate* (the speed with which electrons are stripped from atoms) primarily depends on the density of free electrons in the plasma; the temperature of the plasma; and a basic quantity called the ionization rate coefficient, which, in turn, depends on the atomic structure of the atoms.

"In modeling a reactor plasma," says Roberts, "you *must* know what the ionization rate is because you need it to calculate the density of the impurity ions and the power loss through radiation. The ionization rate coefficients are different for each element and for each ionization level.

A factor related to the ionization rate is the *recombination rate*, a measure of the tendency of free electrons to be recaptured by the ions in the plasma and, again, to waste power through radiation. A particular case, dielectronic recombination,* is an important unknown. Observations of the sun's corona indicate that, at least for lighter elements, dielectronic recombination occurs at a much higher rate than other recombination processes at high temperatures. If this holds true for heavy elements at fusion reactor temperatures, dielectronic recombination could be a significant source of power loss in the plasma.

Although values for these rate coefficients can be calculated from theoretical models, most of them need experimental confirmation. The problem that arises is that the temperatures needed to measure the rates for the more highly ionized forms of heavy elements can be achieved by nothing short of an actual fusion reactor—not a practical solution for two reasons, according to Roberts:

Costs become astronomical at very high temperatures—to raise the temperature by a factor of two may increase costs by a factor of four or more.

In addition, even given an unlimited budget, making a device that operates at fusion temperatures introduces a number of other technical problems that complicate the process.

Scale Model Ions

The method chosen by the NBS researchers can be best described as using "atomic scale models," or more properly, *isoelectronic sequences*.

---

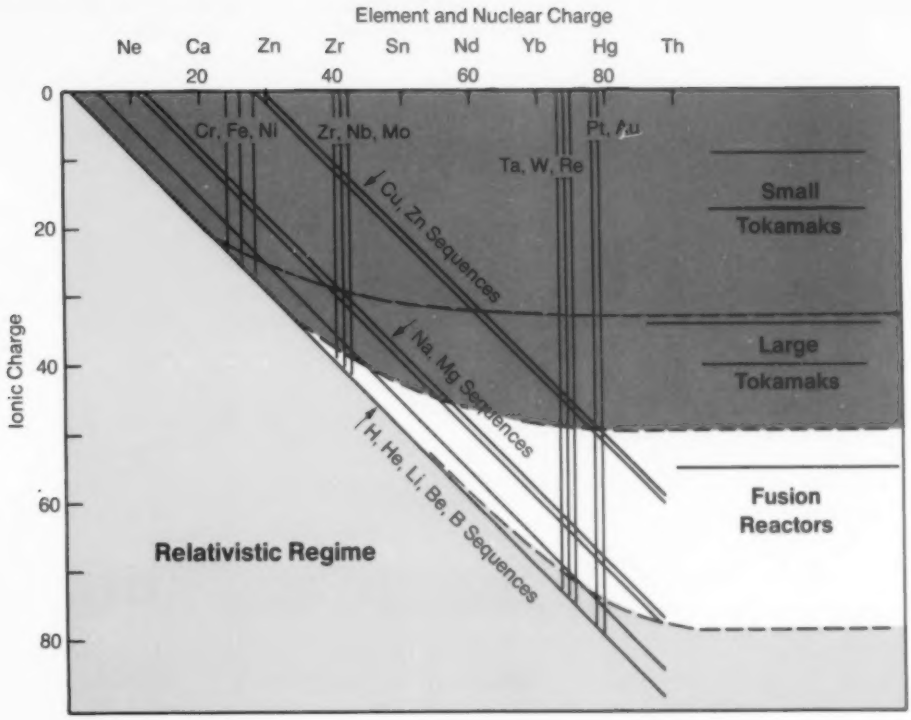
* Dielectronic recombination is a 3-part process:

1) An electron collides with an atomic ion of charge Z and becomes trapped in an outer electron orbit.

2) Simultaneously, the colliding electron excites another electron within the ion of charge Z. 1) & 2) together now form an ion of charge Z-1 (i.e. the Z has captured an additional charge) which has the equivalent of one electron in a doubly-excited state (therefore the name dielectronics).

3) This doubly excited state can now decay to a lower state of the Z-1 ion thus emitting radiation.

This is in contrast to the process where the colliding electron excites an electron of the Z ion, but is not captured and the excited state of the Z ion decays to a lower state within the Z ion thus producing emitted radiation.



An isoelectronic sequence is a series of elements with increasing nuclear charge and increasing ionic charge, but with a constant number of electrons. The hydrogen isoelectronic sequence, for example, begins with hydrogen, with one electron, followed by He^{+1} (helium), Li^{+2} (lithium), Be^{+3} (beryllium), . . . Fe^{+25} (iron), . . . Mo^{+41} (molybdenum) and so on, all with increasing atomic weights, but only one electron.

The important thing about isoelectronic sequences as far as the fusion researchers are concerned is that all the ions in an isoelectronic sequence should have scalable ionization rates and excitation rates. The "heavy" end of the sequences include elements like highly ionized titanium, iron, molybdenum, and other ions of interest to the reactor designers. These are the elements that cannot be studied directly except at the high temperatures of an actual fusion reaction.

But at the lower end of those same sequences are light ions of carbon, nitrogen, oxygen, and the like, which can be studied at temperatures easily reached by the theta pinch. The extrapolation or scaling of the ionization and excitation rates of these lighter ions into the more inaccessible reaches of the sequences is the main goal of the theta pinch project. With this accomplished, the problem of how to make a fusion reactor work can be addressed without actually having to build one.

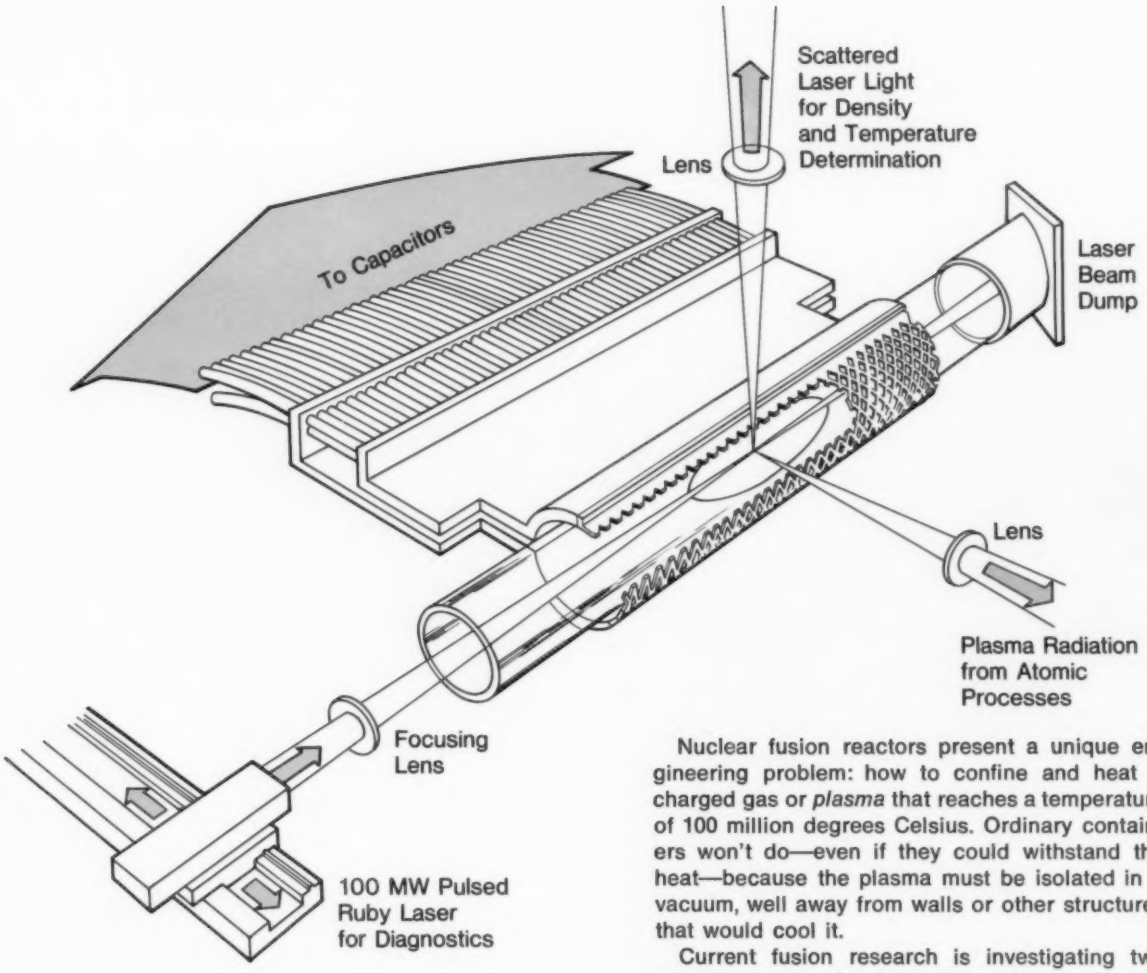
The theta pinch device was chosen for this work, according to Roberts, because it is a well understood plasma source. Results obtained from theta pinch are easily reproducible—an important factor in data gathering.

The NBS theta pinch, just turning two years old, began delivering experimental results about a year ago. The NBS researchers are concentrating initially on the lithium isoelectronic sequence, obtaining data for ions such as O^{+5}. By measuring O^{+5}, the researchers discovered that a previously calculated value was off by a factor of two. This finding indicates the worth of these experimental efforts because oxygen is a major impurity in fusion research devices.

The actual working of the experiment depends on the fact that the plasma does not ionize instantaneously, but rather in stages. The electrons are stripped from the atoms one at a time as the plasma temperature increases, and each successive ionization stage produces temporally varying spectral lines (frequencies) of radiation from the glowing gas. Also, the light from a high-powered ruby laser is sent through the reaction chamber, and the scattering of the laser light by the plasma electrons tells the researchers the temperature and density of the plasma. Combining the recorded time-history of spectral line intensities, the measured temperature and density, and a model of the theta pinch plasma gives the desired rate coefficients. An added benefit of the experimental technique is that it produces spectral data on the impurity ions, information which is useful in diagnosing the impurity concentrations in fusion devices.

The data from the NBS theta pinch provide accurate points to "nail down" the ends of the isoelectronic sequences. For the users of these data who are trying to develop fusion devices—in places like the Princeton Plasma Physics Laboratory, Oak Ridge National Laboratory, and the Massachusetts Institute of Technology—the atomic scale models have a value many times their size. *turn page*

INVISIBLE WALLS FOR AN UNCONTAINABLE GAS



NBS theta pinch plasma analysis system.

Nuclear fusion reactors present a unique engineering problem: how to confine and heat a charged gas or *plasma* that reaches a temperature of 100 million degrees Celsius. Ordinary containers won't do—even if they could withstand the heat—because the plasma must be isolated in a vacuum, well away from walls or other structures that would cool it.

Current fusion research is investigating two separate ways of solving this problem. Inertial confinement, such as is being explored with the SHIVA laser at Lawrence Livermore Laboratory (DIMENSIONS, September 1977), uses fuel contained in small hollow spheres ("microballoons") which are burned and imploded one at a time by high energy laser beams. Each microballoon is heated so quickly that the expanding gas from the outside compresses and heats the remaining core to reaction conditions—the fuel becomes essentially its own container.

Magnetic confinement, more highly developed, uses invisible walls of magnetic force to hold the plasma while it is heated to reaction temperature.

Magnetic confinement systems would hold the fuel at a much lower density than inertial confinement system (10^{14} cm^{-3} compared to 10^{25} cm^{-3}) for a much longer time (approximately one second for a test reactor, compared to 10^{-9} seconds).

The *theta pinch* device at the National Bureau of Standards is an example of one of the simplest types of magnetic confinement.

Although they can be doughnut-shaped, typical theta pinch instruments are simply long tube-shaped devices ringed by a single-turn current carrying coil. Since the gas which forms the fuel for a theta pinch is ionized—each particle carries an electric charge—it can be restrained by the tube-shaped magnetic field, which creates a kind of "bottle."

Once confined, the plasma has to be heated. Since the charged particles will carry an electric current, electrical induction (using the "theta pinch" coil to set up an electric current in the plasma) is a common heating technique. Theta pinch devices heat the plasma by a sudden, powerful increase in the magnetic field strength which squeezes the plasma in on itself, simultaneously increasing the density and raising the temperature. This "pinch" effect is the origin of the name.

Squeezing the plasma tends to force it out the ends of the tube, lowering the density and temperature. This problem, called *diffusion,* is partially solved by another confinement scheme: the *magnetic mirror,* which is also generally tube-shaped, but includes magnets of much greater power at the ends of the tube. These squeeze the ends of the plasma region together and tend to reflect the charged particles back along the tube.

Magnetic mirrors are more popular than theta pinches for actual reactor designs, but a still more popular design is the Tokamak, a name which comes from the Russian acronym for toroidal magnetic chamber. Tokamaks use toroidal or doughnut-shaped magnetic fields with no open ends. This design offers a number of advantages in controlling diffusion and accounts for the fact that the bulk of fusion research is directed towards Tokamak devices.

Both Tokamaks and magnetic mirrors commonly heat their fuel by induction; by bombarding the plasma with high energy, high frequency radio waves; by injecting into the plasma a stream of high energy neutral hydrogen atoms (neutral beam heating); or by some combinations of the three.

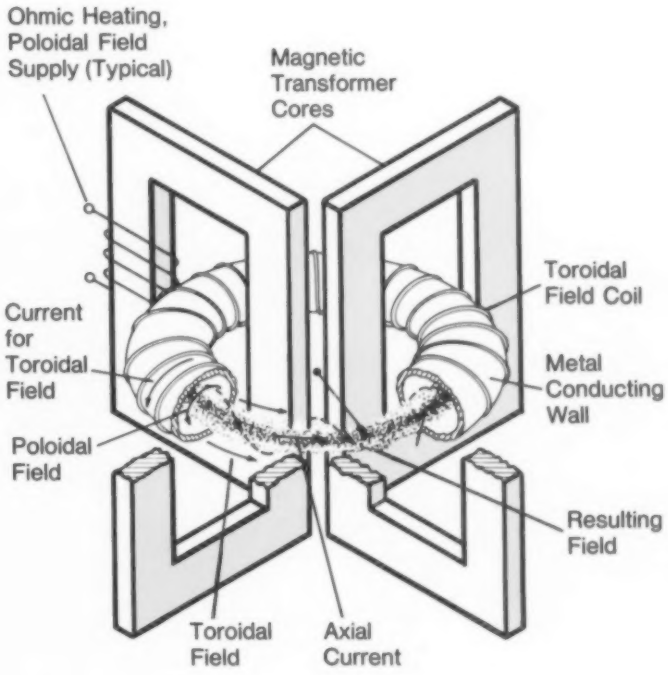
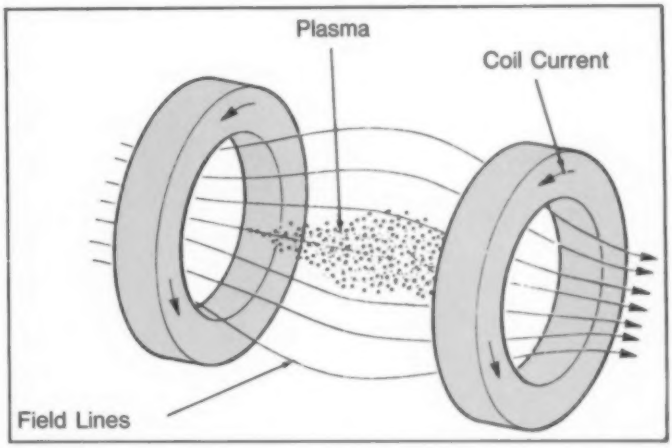


Diagram of a typical Tokamak.



Principle of the magnetic mirror system.

ON LINE WITH INDUSTRY

NEW INSTRUMENT FOR FIELD TESTING SMOKE DETECTORS

by David Chaffee

Smoke detectors are becoming almost as commonplace in our homes as coffee pots or kitchen sinks. Last year 12 million were manufactured in the United States. However, their reliability has become a matter of growing concern.

In response, the National Bureau of Standards has developed an instrument that can test any smoke detector in the country in less than a minute. It is small enough to carry by hand.

Chaffee is a DIMENSIONS staff writer.

Tom Lee with smoke detector tester.

The device was designed in the NBS Center for Fire Research for use by fire department and maintenance personnel in carrying out periodic performance tests. It can be used for the rapid on-site examination of large numbers of installed detectors.

While the sale of smoke detectors has tripled over the past three years, no simple method of testing their sensitivity in the field has been available. Manufacturers estimate that a detector should last about 10 years, but one recent inspection of apartment dwellings revealed that factors beyond the manufacturer's control might reduce that lifetime considerably. In that particular inspection, examiners learned that many dwellers ignored warning signals sounded when bulbs burned out in the photoelectric detectors. As a result, 18 percent of the devices tested didn't work, even though all had been installed within the previous 18 months.

"This is the first universal smoke detector tester available in the country so far as we know," says Tom Lee, a scientist in the NBS Center for Fire Research who spent six months developing the instrument. The device can test all kinds of smoke detectors, whether they are photoelectric or ionization models.

Underwriters' Laboratories has developed a standard which determines how sensitive a detector should be when it has just been made. The tester can be used to determine whether smoke detectors remain sensitive after that. "Certain types of smoke detectors become more sensitive while others can get less sensitive as time goes on," says Lee, who has tested some of the 90 types of smoke detectors located in a Center for Fire Research laboratory.

The NBS instrument—an aerosol generator—produces an aerosol spray of dioctyl phthalate, which has particles with size distribution similar in character to smoke particles from some fires. When a controlled concentration of the aerosol reaches the detector, it will go off in 15 to 30 seconds if it is working properly.

Current plans are to make four experimental models which in turn will be used by various governmental agencies for a 1-year testing period in health care facilities. In addition, the National Fire Prevention and Control Administration, a Department of Commerce Agency, is investigating the use of the device for field studies of residential smoke detectors.

The aerosol generator is made from standardized parts and costs less than $1,000 to build. Anyone interested in obtaining further information may write the Center for Fire Research, National Bureau of Standards, Washington, D.C. 20234.

STANDARDSTATUS

STANDARD FOR CODING CITIES, TOWNS, RELATED PLACES

by Stan Lichtenstein

From urban townships to rural communities and from airports to Indian reservations, more than 136 000 cities, towns and places in the United States are profiled in specially developed codes issued by the National Bureau of Standards.

The codes, made available by the NBS Institute for Computer Sciences and Technology, are for use in information systems and computer applications where there is need to collect, process, and interchange information on American localities.

Implementing a voluntary industry standard (ANS X3.47-1977) of the American National Standards Institute, the NBS standard place codes will also be provided in statistical files of the Census Bureau beginning with the 1980 population census.

Used in conjunction with the two-character standard state code or abbreviation, the standard place code becomes part of a unique seven-character identifier.

Error, confusion or delay in the handling of geographical information can be reduced through use of the new codes. For example, there are 28 "Jefferson" place names in Ohio and the coding system allows for push-button, computerized sorting out of each so that a searcher can find the "right" Jefferson for his particular purpose.

The NBS-provided standard code file offers a variety of aids to effective processing and use of place information, including:

—The state and county where a place is located is also identified by name and standard code.

—When a place is located in more than one county, the file identifies these by name and code. There are 1190 such multi-county places in the file.

—The postal ZIP code of the servicing post office is provided. Where a place is serviced by more than one post office, the ZIP code range is indicated.

—Each place included in the file is categorized into one of eighteen classes. The classification of a place provides further information as to whether it is incorporated, unincorporated, a rural community, a military installation, a transport point, a shopping center, an airport, a township or other type of place.

—Alternate and former names are included with a cross reference to the current place code.

—The world-wide geographic code issued by the General Services Administration (GSA) is included as a cross reference in order to facilitate conversion to the standard by those users who currently employ the GSA codes.

Now being processed by NBS as a proposed Federal standard, the place code is expected to be available in published form in May 1978. The initial version will be published as a Federal Information Processing Standard Guideline pending final approval by the Secretary of Commerce as a government-wide standard.

NBS has made arrangements through the National Technical Information Service (NTIS) for early release of the standard place code file in machine-readable magnetic tapes and on microfiche.

The magnetic tape, identified as PB 274-150, Standard Codes for Named Populated Places and Related Entities of the States of the U.S., is available at a cost of $125. The microfiche, identified as PB 274-146, are available at a cost of $17.50 for a set of 34 fiche. Payment (check, money order, deposit account, or American Express) should be made to the National Technical Information Service, U.S. Department of Commerce, 5285 Port Royal Road, Springfield, Va. 22161. To place telephone orders, call 703/557-4763.

Additional information concerning the standard and its use may be obtained from the NBS Office of ADP Standards Management, Washington, D.C. 20234. Telephone 301/921-3157.

Lichtenstein is a writer and public information specialist in the NBS Public Information Division.

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NON-INTRUSIVE TECHNIQUE MEASURES CONCENTRATION FLUCTUATIONS IN TURBULENT GAS FLOW

Understanding flame and combustion processes in detail has become particularly important recently because of the need for fuel economy, minimizing pollutant formation, and control of fires. Turbulent mixing of fuel and oxidant is the dominant rate controlling step in many types of combustion systems. At the National Bureau of Standards, a new technique has been demonstrated which utilizes Fourier analysis of Raman signals to study concentration fluctuations in turbulent gas flows in a continuous nonintrusive way.*

*Ilan Chabay, Gregory J. Rosasco, and Takashi Kashiwagi.***

Progress in developing more fuel-efficient combustion with less production of pollutants is substantially affected by our understanding of the coupling mechanism between aerodynamic turbulence and chemical reactions. In many types of flames and combustion systems the rate and efficiency of combustion is controlled by the detailed nature of the turbulent mixing of fuel and oxidant gases. Information on the spatial and temporal distribution of temperature and concentration of components is needed.

At NBS we have demonstrated a new technique which measures concentration fluctuations and average concentration of individual chemical species in turbulent gas flow. This was done with a nonintrusive probe (Raman scattering) on a continuous, real-time basis. We measured the spatial distribution of the frequency, the amplitude of concentration fluctuations, and average concentration near a gas jet.

Using equipment at hand in NBS laboratories, we proceeded in the following manner: A gas jet was pointed toward the observation region of a Raman spectrometer. The gas jet consisted of an inner pipe (5 mm in diameter) through which CH_4 passed, and an outer, concentric tube (25 mm in diameter) for air flow. A laser beam was focused at a point within the coaxial shear flow from the jet. The point could be chosen and varied by 3-axis translation of the jet. The small focal volume of the beam also fell within the focal volume of lenses which imaged that region (3×10^{-5} mm^3) onto the slits of a Raman spectrometer. A schematic diagram of the instrument is shown in figure 1. The spectrometer could be tuned to the wavelength shift characteristic of the Raman scattering of the particular species of interest. A photodetector used in a photon-counting mode produced the signal which was analyzed in real time on a device capable of carrying out fast Fourier transform (FFT) algorithms.

In the presence of light emission from a flame, chopping the laser beam improved the signal-to-noise ratio. In this case, the Raman signal of the species is modulated at the chopping frequency, while uncorrelated emissions remained centered about zero frequency. Thus, the spectrum produced by the FFT instrument indicated average concentration as the peak height at the chopping frequency. The shape, width, and height of the sidebands of that peak are related to the periodicity of occurrence of turbulent structures, the size or lifetime of those structures, and the amplitude of the fluctuations. In most cases, spectra were

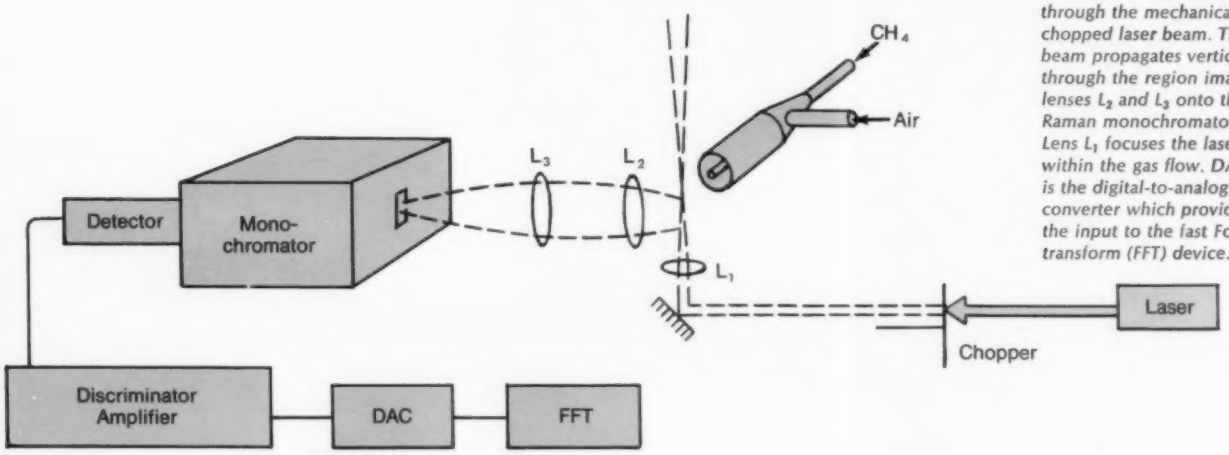

Figure 1—*Schematic diagram of FFT/Raman apparatus. The air and CH_4 from the coaxial jet flow horizontally through the mechanically-chopped laser beam. The beam propagates vertically through the region imaged by lenses L_2 and L_3 onto the Raman monochromator slits. Lens L_1 focuses the laser beam within the gas flow. DAC is the digital-to-analog converter which provides the input to the fast Fourier transform (FFT) device.*

*The Raman effect is the scattering of light from a liquid, solid, or gas with a shift in wavelength from the monochromatic incident radiation.

** Chabay is in the Analytical Chemistry Division, A223 Chemistry Building, 301/921–2862; Rosasco is in the Inorganic Materials Division, A165 Materials Building, 301/921–2780; Kashiwagi is in the Fire Sciences Division, A07 Technology Building, 301/921–3242.

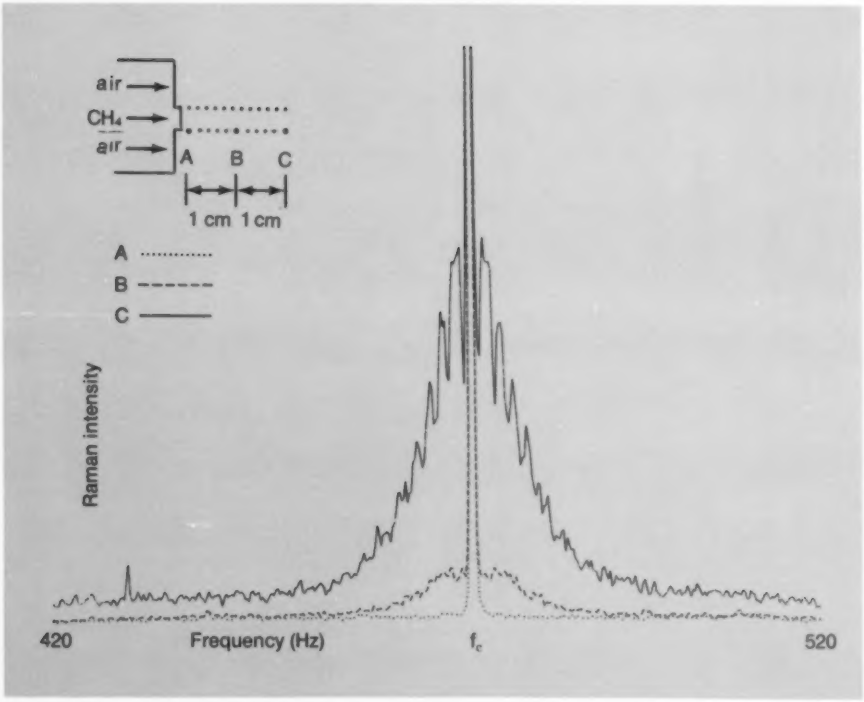

Figure 2—*Three spectra of CH_4 fluctuations taken at the three positions relative to the exit face of the coaxial shear flow indicated in the left corner of the figure. The flow rate of CH_4 and air was the same for all three spectra. The chopper frequency is indicated as f_c. These spectra were normalized to the same peak height.*

taken in a 100-Hz bandwidth centered around the chopping frequency which typically was 465 Hz.

Illustrative results for cold gas flow are given in figure 2. The spectra shown were scaled to the same peak height (average concentration) to emphasize the differences in fluctuation behavior. The positions at which the spectra were measured are indicated in the insert in figure 2. The three fluctuation spectra correspond to measurements at fixed CH_4 and airflow rates and varying positions with respect to the gas jet. Dramatic changes in the amplitude and frequency content of the fluctuations were also evident for variations in flow rate of air or CH_4 at a fixed position.

The Raman spectrometer was tuned to the characteristic vibrational shift for N_2 and fluctuation spectra were obtained. These N_2 spectra show amplitude changes which do not simply correspond to the CH_4 fluctuation spectra taken at the same position and conditions. Significant effects on the frequency content and amplitude of N_2 and CH_4 fluctuations were observed as the cold gas flow was ignited.

The spectra shown are examples of the qualitative and quantitative information which can be obtained on concentration fluctuations in turbulent flow. The frequency spectrum of concentration fluctuations less than 1 percent of the average concentration can be measured for most species near atmospheric pressure. Fluctuations at 5 percent can be determined for some species present at only 1 percent of atmospheric pressure.

We feel that this FFT/Raman technique can be significantly improved with existing technology. The signal-to-noise ratio and the usable frequency range could be increased, which would in turn broaden the variety of measurable species and ranges of concentrations. The technique can have significant impact on studies of other systems such as mixtures of gases and liquids near critical points, and liquid crystals.

THE CENTRAL ROLE OF CHEMICAL KINETICS RESEARCH IN ATMOSPHERIC MODELING AND ENVIRONMENTAL REGULATION

The presence of sulfur dioxide (SO_2) and sulfate aerosols in the earth's troposphere and stratosphere is of great national and international concern. These chemicals have deleterious effects on human health and agriculture and promote materials degradation. Their production in the atmosphere typically stems from the oxidation of organic sulfides (primarily by reaction with hydroxyl radicals). Recent studies of the rates of reaction of hydroxyl radicals with dimethyl sulfide, carbonyl sulfide, and carbon disulfide enable atmospheric modelers to assess the role of these compounds in the global sulfur cycle (i.e. the ultimate formation of SO_2 and associated aerosols).

Michael J. Kurylo, Physical Chemistry Division, A253 Chemistry Building, 301/921–2080.

Computer models of the atmosphere* which are descriptively and predictively accurate are essential tools for formulating pollution abatement strategies, including legislation to regulate the amounts of "pollutant" gases introduced by human means. Such models are used, for example, to predict the effects of man's activities on the production of photochemical smog in the troposphere and the depletion of ozone in the stratosphere.

The models are based on mathematical expressions that account for photolytic, chemical, and transport behavior of all molecular species present in the atmosphere. The validity of the expressions depends on knowledge of the rates of formation and degradation of the active atmospheric constituents. Such knowledge (i.e. of reaction rate constants and mecha-

*For a more detailed discussion of atmospheric modeling, see DIMENSION/NBS, November, 1977.

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nisms) can be obtained only through chemical kinetics research. Thus, an essential part of the NBS program in atmospherics is associated with the precise measurement of elementary rate constants for select gas phase processes at temperatures and pressures directly applicable and relevant to environmental atmospheric modeling.

Typical of our involvement in this area are some recent measurements of the rates of reaction of hydroxyl (OH) radicals with several organic sulfur compounds. These reactions belong to a class of oxidation processes which ultimately convert naturally occurring and man-made sulfides to SO_2 in both the troposphere and stratosphere. The SO_2 thus produced or introduced directly into the atmosphere (via volcanic eruption or the burning of sulfur-containing fossil fuels) is converted into aerosols by further reactions with O, OH, HO_2, H_2O, NO, and NH_3. Thus there is considerable interest in the rates of oxidative conversion of organic sulfides to SO_2 since these reactions can be "rate determining" in the global sulfur cycle.

For many years, hydrogen sulfide (H_2S) generated by decaying vegetation or bacterial reduction of sulfates was assumed to be the principal, gaseous, reduced-sulfur source compound. Recent evidence, however, suggests that biogenic production of organic sulfides such as dimethyl sulfide (DMS) plays an equally important role in the natural transport of sulfur to the atmosphere. Recent detection of carbonyl sulfide (OCS) in the upper troposphere at concentrations significantly higher than expected from natural sources (e.g. volcanic eruption) has increased the list of active sulfides still further. Such observations suggest either the presence of additional direct OCS sources or possibly the production of OCS via oxidation of carbon disulfide (CS_2), whether natural or anthropogenic in origin. While the primary reactive oxidant in our atmosphere is the hydroxyl radical (OH), the only oxidation data available for DMS, OCS, or CS_2 involves their reaction with oxygen atoms. For this reason, we have made the needed direct measurements of their rates of reaction with OH.*

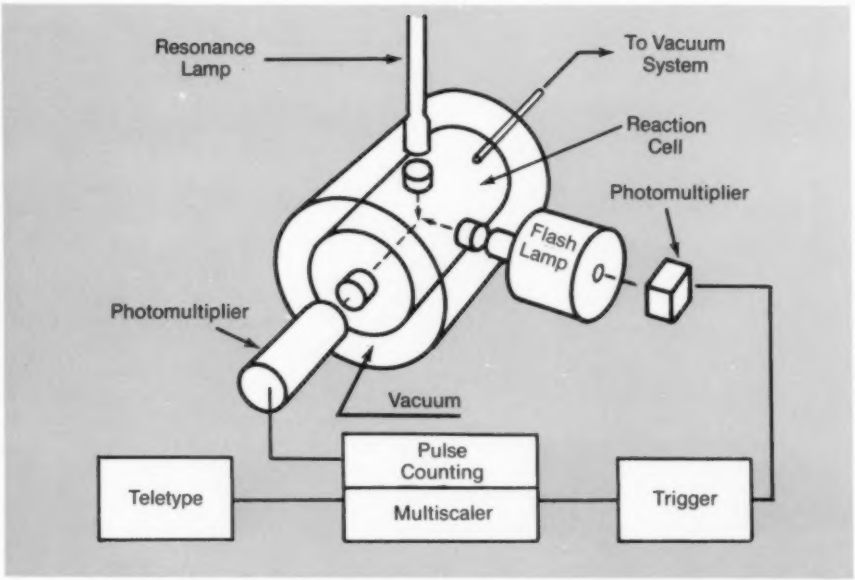

Figure 1—*Flash photolysis resonance fluorescence apparatus.*

The instrument employed for these studies was a temperature-controlled flash photolysis resonance fluorescence apparatus schematized in figure 1. The measurement technique itself was developed at NBS approximately 10 years ago and has gained wide acceptance in laboratories throughout the world as a very precise and accurate method for obtaining elementary gas phase reaction rate constants. With this technique, a mixture containing a free radical source compound, stable reactant, and inert diluent gas is flash photolyzed in the thermostated reaction cell with a spark-discharge flash lamp. A small fraction of the free radicals of interest thus produced absorb radiation emitted by a microwave-powered resonance lamp which is operated continuously. This absorbed resonance radiation is re-emitted (fluorescence) isotropically, and a portion of it is detected by a photomultiplier situated at right angles to both the flash and resonance lamps.

Since the fluorescence signal is proportional to the radical concentration, its real-time decay is a measure of the kinetic lifetime of the radical. The signal, which is accumulated from many such flash experiments using photon counting, is stored in a multichannel analyzer and later analyzed with an on-line computer.

In addition to their direct incorporation into rather elaborate modeling calculations, our data can be used to calculate tropospheric half-lives with respect to reaction with OH for each of the three sulfides. DMS, for example, was found to undergo such extremely rapid reaction that its half-life in the troposphere is slightly less than one day. Thus it is expected to undergo complete oxidation in this atmospheric region. CS_2 and OCS were found to react considerably more slowly (tropospheric OH-reaction half-

*The results of these studies were presented at the 13th Informal Conference on Photochemistry, Clearwater Beach, Florida, January 1978. Two manuscripts detailing the measurements are being prepared for submission to *Chemical Physics Letters*.

lives were approximately six weeks and twenty weeks respectively). Partial oxidation of CS_2 is therefore expected during tropospheric transport. However, since this molecule has not yet been detected in the troposphere, its involvement in the global sulfur cycle remains speculative. OCS on the other hand is expected to undergo vertical transport into the stratosphere where its short wavelength photodissociation eventually leads to SO_2 production.

Similar work is continuing in our laboratory in an attempt to elucidate some of the complex reaction cycles which have direct bearing on the earth's atmospheric and biological well-being.

A NEW ANALYTICAL AND SPECTROSCOPIC TOOL: THE OPTO-GALVANIC EFFECT

When tunable dye lasers are in resonance with electronic transitions of atomic species present in flames and electrical discharges, increased or decreased ionization may result. This change in ionization—the opto-galvanic effect—can be monitored electrically, which eliminates problems associated with laser scatter. The most important uses of the effect have been in analytical spectrometry and spectroscopic applications.

*Peter K. Schenck, John C. Travis, Kermit C. Smyth, and David S. King.**

A recently explored phenomenon, the opto-galvanic effect (OGE), has been developed for use in laser spectroscopy and analytical spectrometry: When a dye laser is tuned into resonance with electronic transitions of atomic species in a suitable plasma, such as a flame or glow discharge, the conductivity of the plasma may change. This results in readily measured voltage changes across the electrodes of the glow discharge or across suitably placed electrodes located near the flame.

Our experiments with discharges involve both continuous wave (CW) and pulsed dye lasers to irradiate hollow-cathode lamps usually used for spectroscopic frequency calibration and atomic absorption analysis. These lamps are convenient atomic reservoirs, and changes induced in the conductivity of their discharges may readily be observed. These changes may be positive or negative and are attributed to mechanisms which either enhance or inhibit the ionization rates in the discharge. When CW lasers are used, they are mechanically chopped, and phase sensitive detection is employed to monitor the effects of the laser on the

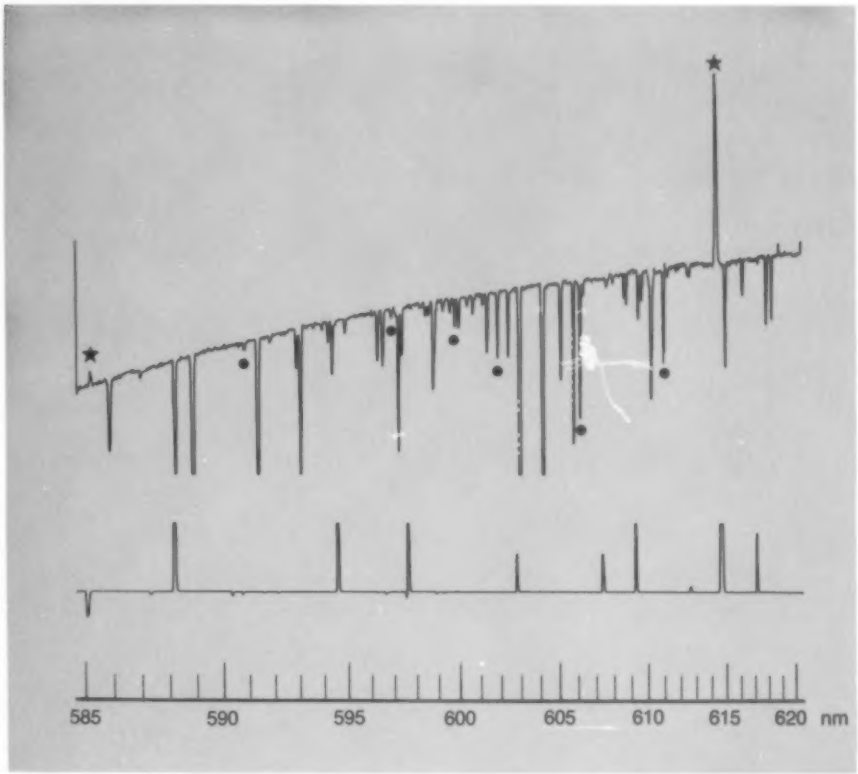

Figure 1—*Opto-galvanic spectrum of a barium/argon hollow-cathode lamp. The upper spectrum is the OGE signal obtained by scanning a CW dye laser from 585 nm to 620 nm while irradiating a commercial hollow-cathode lamp (operating at 15 mA) with a barium-spiked cathode and argon fill gas. The laser power was stabilized at 150 mW throughout the scan. The starred peaks are due to barium ion transitions and the dotted peaks are neutral barium transitions. All other lines are due to neutral argon. The lower spectrum is a simultaneously generated spectrum from a hollow-cathode lamp containing neon. This spectrum is used to calibrate the non-linear wavelength scan of the dye laser.*

*Schenck and King are with the NBS Laser Chemistry Program, A329 Materials Building, 301/921-2766. Travis is in the Analytical Chemistry Division, A211 Chemistry Building, 301/921-3327. Smyth is in the Center for Fire Research, B06 Technology Building, 301/921-2021.

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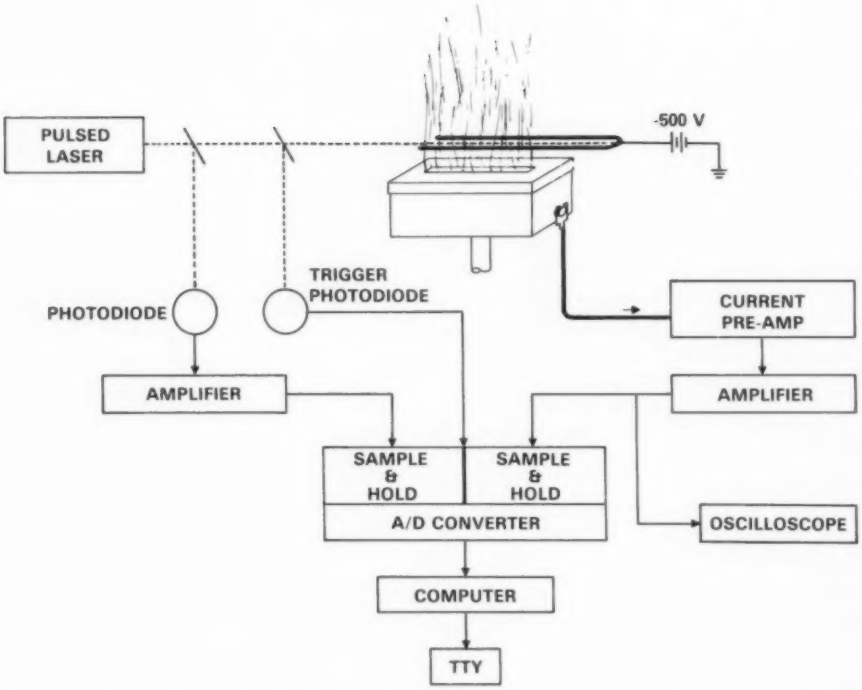

Figure 2—*Analytical apparatus for trace metal detection in water utilizing the opto-galvanic effect. A commercial dye laser is directed into an analytical burner normally used in atomic absorption work. Electrodes are placed on either side of the flame and held at a potential of −500 volts. The burner head is allowed to float above ground potential and serves as the other electrode. When metal species in the flame are irradiated with laser light at a frequency corresponding to an atomic transition, increased thermal ionization results. This yields a measurable current change which is recorded. The current is proportional to the concentration of metal atoms present in the flame. With this apparatus, several metallic species have been detected at the sub parts-per-billion by mass level in water.*

discharge. Gated electronics are utilized when pulsed laser sources are used.

Figure 1 shows two OGE spectra simultaneously recorded from a barium/argon hollow-cathode lamp and a neon-filled hollow-cathode lamp, both irradiated by the same CW dye laser. The OGE signals from the neon lamp exhibit both negative and positive voltage changes and correspond to absorption from many neon excited states. The negative voltage changes result when neon atoms are promoted by the laser to higher-lying energy levels from which they are more readily ionized. This increases the conductivity of the discharge, thus lowering the voltage drop across it in our apparatus. The positive voltage changes correspond to neon transitions which deplete the neon populations in high-lying metastable states, either directly by radiative decay or indirectly via collisional processes. These metastable states play a significant role in maintaining the discharge; their depletion quenches the discharge, thus decreasing its conductivity.

This second mechanism competes with collisional ionization by electrons. As the discharge current is increased, collisional ionization becomes more important, and all the voltage signals become negative at high discharge currents.

The use of known OGE spectra is a convenient means of calibrating other optical or OGE spectra. The non-linearity of our laser's tuning element is evident in figure 1, and the simultaneous recording of a known spectrum is essential. OGE signals have been seen in a variety of lamps containing argon, xenon, and krypton—as well as those containing neon. This selection of carrier gases, combined with the large number of cathode materials in commercially available hollow-cathode lamps, allows one wide latitude in the choice of lamps for spectral calibration for any laser experiment in the near ultraviolet and visible. The linewidth of these absorptions is typically $\leq$ .004 nm. Thus, with this technique we are able to measure laser linewidth and absolute laser wavelength very precisely. It is important to note that excited-state/excited-state transitions as well as ground-state/excited-state transitions are available, a fact that dramatically increases the number of calibration wavelengths.

Our current research program includes efforts to further characterize the OGE in discharges. For example, the temporal behavior of the photo-induced voltage changes offers interesting insights into the competition between radiative and col-

Table 1—*Detection limits of metal species by OGE and AA in nanograms per milliliter*

Element	λOGE	Detection Limit	λAA	Detection* Limit
Cr	298.6	2	357.9	5
Cu	324.8	100	324.8	5
Fe	302.1	2	248.3	5
Ga	287.4	.07	287.4	70
K	294.3	1	766.5	5
Mg	285.2	.1	285.2	.3
Mn	279.5	.3	279.5	2
Na	285.3	.05	589.0	2
Ni	300.2	8	232.0	5
Pb	280.2	.6	283.3	30
Sn	284.0	6	224.6	60

*AA detection limits are from E. E. Pickett and S. R. Koirtyohan, Anal. Chem. 41, 28A (1969).

lision processes. In addition, we have been able to detect signals corresponding to atomic ion absorption, which is most difficult to observe by other optical techniques. In a barium hollow-cathode lamp with argon as a fill gas, two barium ion transitions have been observed, as is clearly demonstrated by the top spectrum of figure 1.

Similar signals have been observed from several europium ion lines in a europium hollow-cathode lamp. The mechanism of the ion signals is not yet fully understood, but it most likely involves collisional processes which effectively deplete the metastable argon population, thus decreasing ionization in the discharge. This is an active area of research at NBS, as ion detection by the OGE may aid in plasma and flame diagnostics.

The OGE in hollow-cathode discharges has also proven to be a powerful means of frequency-locking CW dye lasers to a large number of atomic transitions. This has been accomplished at NBS by using the OGE to provide the electrical signals required for the feedback loop. Lasers at NBS have been locked to transitions in a variety of lamps, including neon, sodium, and barium. Equally suitable signals can be obtained from any of the lines shown in figure 1.

The OGE may also be observed in flames seeded with metal atoms. The apparatus utilizes a premix slot burner normally used to atomize samples for atomic absorption analysis (see figure 2). This burner has been employed to study the laser-enhanced thermal ionization of metal atoms in flames. In particular, our efforts have been aimed at the use of the OGE in flames as an analytical tool for trace metal detection in water. As illustrated in figure 2, electrodes must be added to the flame to measure any changes in the flame's conductivity induced by the laser. As in the hollow-cathode lamps, we are not troubled by the usual problems of laser scatter and background inherent with optical monitoring. With this apparatus, the detection limit of several species has been extended to the sub parts-per-billion by mass level. The results of this effort are listed in table 1, where they are compared to current atomic absorption detection limits. The NBS experimental program includes studies of interference effects as well as comparisons of detection limits involving different transitions of the same species.

STAINLESS STEEL STANDARD REFERENCE MATERIALS

The NBS Office of Standard Reference Materials announces the availability of a new stainless steel material certified for its chemical composition and available in two different forms.

SRM 367 is in the form of chips intended for use in chemical methods of analysis, and SRM 1267 is in the form of disks 32 mm (1¼ in) in diameter and 12.7 mm (½ in) thick intended for use in optical emission and x-ray spectrometric methods of analysis.

This is a ferritic stainless steel widely used because of its high resistance to corrosion and scaling at high temperatures, especially for intermittent service. This type of stainless steel often is used in sulfur-bearing atmospheres. It is produced in a variety of forms such as bars, plates, sheets, strips, tubing, and wire.

These two new SRM's have been prepared under the auspices of the ASTM/NBS Research Associate Program. SRM 367 is certified for its chemical composition as follows (wt%): C 0.093, Mn 0.315, P 0.018, S 0.016, Si 0.58, Cr 24.19, V 0.08, N 0.168, and Ni 0.29. The certified chemical composition of SRM 1267 is nearly identical to that of SRM 367.

SRM's 367 and 1267 may be purchased from the Office of Standard Reference Materials, Room B311, Chemistry Building, National Bureau of Standards, Washington, D.C. 20234. SRM 367 is issued in units of 150 g and is priced at $46 per unit. SRM 1267 is issued in units of disks, 32 mm in diameter and 12.7 mm thick, and is priced at $44 per unit.

CONFERENCES

For general information on NBS conferences, contact Sara Torrence, Public Information Division, Washington, D.C. 20234, 301/921-2721.

BRANSCOMB TO ADDREESS COMPUTER SYMPOSIUM

Dr. Lewis M. Branscomb, IBM Corporation Chief Scientist and Vice President for Research, and a former director of the National Bureau of Standards, will deliver the keynote address at the "Trends and Applications: Distributed Processing" symposium to be held on May 18, 1978 at NBS headquarters in Gaithersburg, Maryland.

The Trends and Applications symposia, cosponsored by NBS and the Institute of Electrical and Electronics Engineers (IEEE) Computer Society Eastern Area Committee and cooperating Washington, D.C., groups, are annual events that have provided a leading forum on developments in the planning, implementation, evaluation and use of computers and communications.

This year's symposium will focus on practical experiences with distributed processing, new research results, and tutorial papers.

Among 1978 symposium topics are: Networks of processors, multiprocessor systems, distributed data bases, interprocess communication, programming and operation systems, security, performance evaluation, and novel applications.

Symposium committee members are: Helen M. Wood, Conference Chairperson, NBS, 301/921-2601; Dr. Ashok Agrawala, Program Chairperson, University of Maryland, 301/454-4251; and Shirley Ward Watkins, NBS liaison, 301/921-2601.

For program information, contact Ms. Watkins.

NBS TO HOST ATTIC VENTILATION WORKSHOP

Summer energy savings achieved by using various types of ventilation equipment will be discussed at a one day workshop July 13, 1978, at the National Bureau of Standards in Gaithersburg, Maryland.

The Workshop on Summer Attic Ventilation and Whole House Fan Ventilation is sponsored by the NBS Center for Building Technology. It is part of a program of studies in this field being conducted in collaboration with the Department of Energy and the attic ventilation industry. The meeting will provide a forum for technical discussions to assess summer energy savings that may be achieved from use of powered and nonpowered attic ventilating equipment and whole house fans. Papers on experimental and mathematical modeling studies will be presented.

Representatives from gas and electric utility companies, ventilating equipment manufacturers, trade associations for the ventilation, insulation and roofing industries, various government agencies and other industry groups are expected to attend.

Persons interested in contributing papers or participating in the workshop should contact: Douglas M. Burch, B104 Building Research Building, 301/921-3513.

TIME AND FREQUENCY SYMPOSIUM

Papers are being solicited for a symposium on time and frequency to be held August 1-4, 1978, in Helsinki, Finland. The symposium will be chaired by Helmut Hellwig of the U.S. National Bureau of Standards, with cochairmen Bernard Guinot of the Bureau International de l'Heure and Lauren Reuger of the Johns Hopkins University Applied Physics Laboratory.

This symposium, part of the 19th General Assembly of the Union Radio Scientifique Internationale (URSI), is intended to bring together those scientists involved in time and frequency generation and distribution and those who rely on precise time and frequency in their measurement. It is hoped that such a dialogue will lead to increased understanding and to new opportunities for international cooperation.

Precise time dissemination and coordination are having an increasing impact on the scientific and technical world. They lead to: fundamental new insights into nature; novel opportunities in position location, navigation and communication; effective use of existing energy resources and the discovery of new ones; and development of peaceful, worldwide cooperation.

The tentative program comprises review papers on time, frequency and length metrology (co-sponsored by URSI Commission D) and on applications of time and frequency to navigation, communication, and relativity.

Original papers are being solicited now in the areas of precision time and frequency dissemination and coordination including one- and two-way microwave satellite links, ground or satellite-based laser links, the utilization of existing or proposed communication networks for time distribution and all other areas of topical relevance including application and use aspects.

Symposium papers will be published in the journal *Radio Science*.

Persons interested in presenting papers should submit abstracts by March 1978 to Dr. H. Hellwig, Time and Frequency Division, National Bureau of Standards, Boulder, Colo. 80302 or call 303/499-1000, ext. 3277.

CONFERENCE CALENDAR

May 8-10

SYMPOSIUM ON REAL-TIME RADIOGRAPHIC IMAGING, NBS, Gaithersburg, MD; sponsored by NBS and the American Society for Testing and Materials; contact: Donald A. Garrett, A106 Reactor Building, 301/921-2167.

May 9-12

IONIZING RADIATION MEASUREMENT, NBS, Gaithersburg, MD; sponsored by NBS; contact: E. H. Eisenhower, C233 Radiation Physics Building, 301/921-2551.

May 18

TRENDS AND APPLICATIONS SYMPOSIUM, NBS, Gaithersburg, MD; sponsored by NBS, IEEE Computer Society; contact: Shriley Watkins, B212 Technology Building, 301/921-2061.

May 30-June 1

PROCUREMENT: MANDATED PROGRAMS UNDER RCRA AND EPCA, NBS, Gaithersburg, MD; sponsored by NBS and National Governors Association; contact: Harvey Yakowitz, B164 Materials Building, 301/921-2343.

June 5-7

3RD INTERNATIONAL SYMPOSIUM ON ULTRASONIC IMAGING AND TISSUE CHARACTERIZATION, NBS, Gaithersburg, MD; sponsored by NBS and National Institutes of Health; contact: Melvin Linzer, A329 Materials Building, 301/921-2858.

June 7-9

1ST INTERNATIONAL SYMPOSIUM ON ULTRASONIC MATERIALS CHARACTERIZATION, NBS, Gaithersburg, MD; sponsored by NBS and American Society for Nondestructive Testing, contact: Harry Berger, B252 Polymers Building, 301/921-3281.

June 12-13

MICROCOMPUTER BASED INSTRUMENTATION CONFERENCE, NBS, Gaithersburg, MD; sponsored by NBS, IEEE Computer Society; IEEE Group on Instrumentation and Measurement; contact: Bradford Smith, A130 Technology Building, 301/921-2381.

June 15

TOOLS FOR IMPROVED COMPUTING IN THE 80's, NBS Gaithersburg, MD; sponsored by NBS, Washington, D.C. Chapter of the Association for Computing Machinery; contact: Trotter Hardy, A367 Technology Building, 301/921-3491.

June 19-21

GAS KINETICS CONFERENCE, NBS, Gaithersburg, MD; sponsored by NBS and the Committee on Chemical Kinetics, NBS, Committee on Chemical Kinetics of the National Academy of Sciences/National Research Council; contact: David Garvin, B154 Chemistry Building, 301/921-2771.

June 26-29

CONFERENCE ON PRECISION ELECTROMAGNETIC MEASUREMENTS, Ottawa, Ontario, Canada; sponsored by Institute of Electrical and Electronics Engineers, U.S. National Committee-International Union of Radio Science, and NBS; contact: Dee Belsher, NBS, Boulder, Colo., 303/499-1000, ext. 3981.

***July 13**

WORKSHOP ON SUMMER ATTIC VENTILATION AND WHOLE HOUSE FAN VENTILATION, NBS, Gaithersburg, MD; sponsored by NBS; contact: Douglas M. Burch, B122 Building Research Building, 301/921-3513.

July 17-20

FOURTH ANNUAL CONFERENCE OF THE AMERICAN ASSOCIATION FOR CRYSTAL GROWTH, NBS, Gaithersburg, MD; sponsored by NBS and AACG; contact: Robert L. Parker, B164 Materials Building, 301/921-2961.

***August 14-16**

5TH INTERNATIONAL SYMPOSIUM ON CONTROLLED RELEASE OF BIOACTIVE MATERIALS, sponsored by NBS; contact: Frederick Brinckman, A325 Materials Building, 301/921-2847.

September 18-22

CHARACTERIZATION OF HIGH-TEMPERATURE GASES, NBS, Gaithersburg, MD; sponsored by NBS, contact: J. Hastie, A307 Materials Building, 301/921-2859.

October 4-6

NATIONAL CONFERENCE OF STANDARDS LABORATORIES, NBS, Gaithersburg, MD; sponsored by NBS and the National Conference of Standards Laboratories; contact: Brian Belanger, A345 Physics Building, 301/921-2805.

****October 24-25**

CONSTRUCTION DOCUMENTATION CONFERENCE; NBS, Gaithersburg, MD; sponsored by NBS, the Construction Specifications Institute, and the Guide Specifications Committee of the Federal Construction Council; contact: Roger Rensburger, A151 Technology Building, 301/921-3126.

***November 13-15**

CERAMIC MACHINING AND SURFACE FINISHING II, NBS, Gaithersburg, MD; sponsored by NBS, Office of Naval Research, Air Force Office of Scientific Research, and the American Ceramic Society; contact: Bernard Hockey, A345 Materials Building, 301/921-2901.

***December 4-6**

WINTER SIMULATION CONFERENCE, NBS, Miami Beach, FL, sponsored by NBS; American Institute of Industrial Engineers; Systems, Man, and Cybernetics Society, Institute of Electrical and Electronics Engineers; Operations Research Society of America; College of Simulation and Gaming, The Institute for Management Sciences; and Society for Computer Simulation; contact: Paul F. Roth, B250 Technology Building, 301/921-3545.

* New Listings
** Conference originally scheduled for March 13-15, postponed to October 24-25.

PUBLICATIONS

1976 NBS PUBLICATIONS CATALOG NOW AVAILABLE

Publications of the National Bureau of Standards, Burris, B. L., Ed., Nat. Bur. of Stan. (U.S.), Spec. Publ. 305 Suppl. 8, 728 pages (June 1977), Stock No. 003-003-01743-4, $8.25.

A complete listing of all scientific, technical, and consumer publications issued by the Commerce Department's National Bureau of Standards during 1976 is now in print and available. This catalog documents the largest annual production of printed pages in the Bureau's history.

The catalog cites some 2,200 papers, consisting of 60,728 pages, and tells how each paper can be obtained.

It is the first to include citations of patents given to NBS inventors and grantee-contract reports prepared by NBS contractors. These additions now join the vast list of research papers, applied mathematics series, interagency reports, national standard reference data series, building science series, monographs, handbooks, special publications, federal information processing standards publications, consumer information series, voluntary product standards and technical notes that are in the catalog.

Each publication is cited by title, authors, volume taken from, abstract, and key word. Citations for papers published in the Bureau's formal program are organized by NBS publications series; NBS papers in non-NBS media are listed separately by number. In addition, a special section categorizes all 1976 papers by major primary subject area.

The 1976 catalog also contains information on previous NBS catalogs, and on the availability of NBS papers published in past years. Papers published prior to 1976 but not listed in previous catalogs are also included.

TEACHER AIDS

The following materials produced by agencies of the federal government have been examined and recommended by DIMENSIONS/NBS for their potential value as supplements to the classroom or school library.

Food Waste: An Opportunity to Improve Resource Use (CED-77-118)

An estimated 20 percent or $31 billion worth of U.S. food is lost or wasted each year, this 80-page paperback "Report to the Congress by the Comptroller General of the United States" indicates. Illustrated with tables and charts, the report looks into many aspects of the U.S. food system related to loss from field to kitchen. Included is an analysis of "plate waste" in the National School Lunch Program. America has a large conservation potential and about 49 million people "could have been fed in 1974 just from the lost food grains, meats, sugar, oilseeds, vegetables, and fruits," according to the report. Offered without charge to educators and non-profit organizations ($1 a copy to others), the report may be ordered from:

U.S. General Accounting Office
Distribution Section, Room 4522
441 G Street, N.W.
Washington, D.C. 20548

Lunar Rocks for Educational Use

The National Aeronautics and Space Administration (NASA) offers a package of materials from the moon on free loan to educational institutions having a curriculum in the geosciences. Eleven polished thin sections of lunar rocks and soils compose the package. The lunar rock samples illustrate three general lithologic types found on the moon—plutonic rocks, volcanic rocks, and polymict breccias. Soil samples include fragments of local bedrock, various rocks and glasses from remote sources, and other fine particles and glasses related to rapid heating, small meteorite impacts, and fusion of rock material. Faculty members may apply for use of the Thin Section Educational Package by writing to:

Lunar Sample Curator
Lyndon B. Johnson Space Center
Code TL
Houston, TX 77058
Phone: 713/483-3274

Computerized Robots

A computer-controlled robot is the star of a 16 mm, 20-minute color film that demonstrates the potential for using robots in industry to expedite production and relieve human workers of dull or dangerous factory tasks. The film, called *Hierarchical Control,* concerns efforts at the National Bureau of Standards to improve robot technology. Available on free loan from:

Association Films
600 Grand Avenue
Ridgefield, NJ 07657

For purchase information, contact:

Public Information Division
National Bureau of Standards
Room A627, Administration
Washington, D.C. 20234
Phone: 301/921-3181

Building Technology

Crist, R. A., and Cattaneo, L. E., Eds., Earthquake Resistant Masonry Construction. Proceedings of a National Workshop held at the National Bureau of Standards, Boulder, CO, Sept. 13-16, 1976, Nat. Bur. Stand. (U.S.), Bldg. Sci. Ser. 106, 372 pages (Sept. 1977) Stock No. 003-003-01872-4, $6.

Meese, W. J., and Beausoliel, R. W., Exploratory Study of Glowing Electrical Connections, Nat. Bur. Stand. (U.S.), Bldg. Sci. Ser. 103, 29 pages (Oct. 1977) Stock No. 003-003-01859-7, $1.30.

Computer Science and Technology

Barbera, A. J., Computer Science and Technology: An Architecture for a Robot Hierarchical Control System, Nat. Bur. Stand. (U.S.), Spec. Publ. 500-23, 227 pages (Dec. 1977) Stock No. 003-003-01874-1, $4.25.

Chattic, A. G., Computer Science and Technology: Guide to Computer Program Directories, Nat. Bur. Stand. (U.S.), Spec. Publ. 500-22, 168 pages (Dec. 1977) Stock No. 003-003-01867-8, $3.25.

Gait, J., Computer Science and Technology: Validating the Correctness of Hardware Implementations of the NBS Data Encryption Standard, Nat. Bur. Stand. (U.S.), Spec. Publ. 500-20, 46 pages (Nov. 1977) Stock No. 003-003-01861-9, $1.60.

Ruthberg, Z. G., McKenzie, R. G., Eds., Computer Science and Tecnology: Audit and Evaluation of Computer Security. Proceedings of the NBS Invitational Workshop held at Miami Beach, Florida, Mar. 22-24, 1977, Nat. Bur. Stand. (U.S.), Spec. Publ. 500-19, 256 pages (Oct. 1977) Stock No. 003-003-01848-1, $4.

Health and Safety

Kramer, J. J., Ed., The Role of Behavioral Science in Physical Security. Proceedings of the First Annual Symposium, April 29-30, 1976, Nat. Bur. Stand. (U.S.), Spec. Publ. 480-24, 122 pages (Nov. 1977) Stock No. 003-003-01868-6, $3.

Richmond, J. C., Image Quality of Monochrome Television Cameras, Nat. Bur. Stand. (U.S.), Spec. Publ. 480-25, 14 pages (Oct. 1977) Stock No. 003-003-01855-4, 90 cents.

Electromagnetic Metrology

Andrews, J. R., and Arthur, M. G., Spectrum Amplitude—Definition, Generation and Measurement, Nat. Bur. Stand. (U.S.), Tech. Note 699, 100 pages (Oct. 1977) Stock No. 003-003-01865-1, $2.75.

Electronic Technology

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NEWS BRIEFS

THE TIME HAS COME TO TALK OF SHOES. How can the U.S. footwear industry develop a competitive edge in its home market? The Department of Commerce thinks that certain manufacturing technologies could be adapted and developed for this purpose. This possibility will be explored in a symposium June 1 and 2 at NBS in Gaithersburg, MD. The meeting is part of a 3-year Commerce program to help restore the vitality of the domestic footwear industry. Persons interested in attending the free symposium should contact Margery King, A1123 Administration Building, NBS, Wash., D.C. 20234.

MEASURE FOR MEASURE. A pound of rice is a pound of rice and quart of milk is a quart of milk in every store and market in the United States--and the same will be true of new metric sizes. The reason is found in the quiet but vital efforts of the nation's weights and measures officials. The daily work of these unsung guardians of consumer rights is the subject of a new 14-1/2 minute color film produced by the National Bureau of Standards and the National Conference on Weights and Measures. Prints of "The Marketplace" are available on free loan (plus cost of return mailing) from Association Films, Inc., 866 3rd Ave., New York, NY 10002.

WASTE NOT, WANT NOT--SAYS UNCLE SAM. Both the Energy Policy and Conservation Act and the Resource Conservation and Recovery Act prescribe procurement policies for federal state, and local agencies. The overlapping effects of these policies on the purchasing of products such as recycled oil, tires, and paper will be discussed at an NBS conference on May 30 and 31, 1978. The goal is to establish a continuing forum for industry and government agencies on ways to encourage resource recovery and materials and energy conservation through purchasing processes. The conference is cosponsored by NBS, the National Governors' Association, and EPA. Contact Joseph Berke, Office of Recycled Materials, NBS, Wash., D.C. 20234, 301/921-2343.

SCIENCE INDICATORS--1976. On January 20, 1978, the President submitted to the Congress the Ninth Annual Report of the National Science Board, entitled Science Indicators--1976 (NSB 77-1). This report is the third in a series of indices of the strengths and weaknesses of science and technology in the U.S. and the changing character of that activity. Copies are available from the Superintendent of Documents, U.S. GPO, Wash., D.C. 20402. Price is $4.75 per copy. Request Stock No. 038-000-00341-1.

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